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STUDIES ON THE STORAGE OF WHEATEN FLOUR: II. THE ABSORPTION OF OXYGEN BY FLOUR WHEN STORED UNDER VARIOUS CONDITIONS [1]

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Introduction and Review of Some Earlier Work on Auto-Oxidation

During storage many substances undergo changes; for example, milk turns sour, meat goes "bad," butter turns rancid, rubber perishes, and many oils, such as linseed oil, thicken and ultimately solidify. The changes taking place in milk and meat are largely due to bacterial action but with butter, rubber, and linseed oil it is auto-oxidation by air which causes the changes.

The theory of auto-oxidation and the mechanism of the reactions involved have been studied by many workers and comprehensive reviews on this subject have been given by Moureu and Dufraisse (1926) and by Milas (1932).

The molecules of substances that are susceptible to auto-oxidation contain double bonds or unsaturated linkages and it is to these that the oxygen becomes attached during auto-oxidation. The resulting compound which contains unstable peroxide linkages then breaks up into aldehyde and other decomposition products. It is such decomposition products which cause the odour of rancid fat.

The rancid odour of fat is only apparent when oxidation is well advanced and many tests have been devised for testing for incipient rancidity. Of these, many make use of the peroxide formation which occurs at the double bond, an example of such a test being that devised

[1] First issued in February, 1934, as Confidential Report No. 29 of the Research Association of British Flour-Millers. Released for publication by the Council of the Research Association, November, 1935.

by Kreis (1902). In this test the fat is mixed with concentrated hydrochloric acid and a 1% solution of phloroglucinol in ether, a red or pink colour being formed if the fat has undergone oxidation.

Kerr (1918), and Taffel and Revis (1931) among others have made modifications to this test.

These colour tests, although useful in certain cases, have not proved very satisfactory as means of following the course of oxidation, and the usual method of examination is to measure the actual uptake of oxygen during the period of storage.

The method adopted by Greenbank and Holm (1925) and by other workers is to place the substance to be investigated in a closed glass vessel, connected with a manometer or other pressure measuring device, replace the air in the apparatus with oxygen and keep the whole at constant temperature. As the oxygen is absorbed the pressure inside the vessel decreases and this decrease is measured at intervals.

In general, there is an initial period, known as an *induction period,* during which no appreciable absorption of oxygen takes place. After this period, absorption increases rapidly. The length of the induction period is the best indication of the susceptibility of any substance to auto-oxidation.

Susceptibility to auto-oxidation is greatly influenced by certain factors.

Emery and Henley (1922), for example, found that fats did not turn rancid when stored out of contact with air. In the presence of carbon dioxide, which was apparently oxygen free, rancidity, however, did develop. It also developed more quickly in oxygen than in air and was hastened by light and by the presence of metals. All metals were not equally active in promoting oxidation and the degree of activity was not connected with the degree of chemical attack of the fat on the metal.

Greenbank and Holm (1924) found that the presence of fatty acids of high molecular weight increased the rate of oxidation of butter-fat as also did the natural volatile constituents of butter. Old fats were found to oxidise more quickly than fresh fats even when their acidities were the same. The presence of water in the fat was found to delay oxidation.

Anderegg and Nelsen (1926) found that cod liver oil when mixed with dry substances such as milk-powder or starch rapidly decomposed but that the addition of alcohol, wheat germ oil, or water exerted a protective action. The degree of protection by water was found to vary with the quantity used. These workers also noticed that there was a relationship between the state of fat preservation and the nutritional value of the ration containing the fat.

Mattill (1927, 1931) reported that the destruction of vitamins A

and E is associated with the oxidative changes that lead to development of rancidity in fats. He noted that this oxidation could be hastened by ferrous sulphate and delayed by wheat germ oil.

Fine and Olsen (1928) examined the development of rancidity in grain products. These workers stored a wholemeal, a patent flour, wheat germ, and other products of various moisture contents at temperatures of 50° C. and 35° C. and also at room temperature. With products of the same moisture content, rancidity developed first in the group stored at 50° C., then in those stored at 35° C., and finally after a considerable lapse of time in those stored at room temperature. In samples of moisture content of 2% or less it developed rapidly but moisture contents of 5% or over were definitely protective. Glycerol was also found to have a protective action with grain products.

Roller (1931) found that not all samples of wheat germ oil delayed oxidation when added to fats. Samples that were effective had higher acetyl values than those that were not effective and he considers that it is the hydroxyl group associated with the glycerol radical in the fat or fatty acid that gives wheat germ oil its power of delaying auto-oxidation.

Triebold and others (1931, 1932, 1933) found that the keeping quality of biscuits is not necessarily related to the keeping quality of the fats used in their manufacture, in some cases biscuits of good keeping quality having been made from fats of poor keeping quality.

Substances which help auto-oxidation are known as *pro-oxygens,* those that delay it as *anti-oxygens.* Large numbers of these substances have been made the subjects of patent specifications affecting many industries.

During storage under normal circumstances the colouring matter of flour is bleached (see Farrari and Bailey, 1929) and with some flours if not with all there is an improvement in the baking quality as a result of the storage. To some extent the natural effects of age can be produced by means of bleaching agents and improvers, a class of substances which are, in general, powerful oxidising agents.

Because of this it has been generally assumed that the effects of age on flour are due to oxidation by atmospheric oxygen. The question of what happens during ageing and during treatment of a flour with improvers is of considerable importance to the milling industry but so far has received but little attention.

Experimental

In the following pages an account is given of a preliminary investigation undertaken with the object of throwing some light on the factors underlying the natural ageing of flour.

The account is divided into three parts:

Part I deals with experiments in which flours were stored in an atmosphere of air at a temperature of 25° C. and the oxygen absorption was measured from day to day.

Part II deals with experiments in which flours were stored in an atmosphere of oxygen in an improved apparatus and at two temperatures, 25° C. and 60° C. The oxygen absorption was measured and the effects of the storage on the flours were investigated by means of certain analytical tests.

Part III deals with experiments in which large samples of flour were stored in air in tins and were examined at regular intervals both by means of baking tests and by analytical methods.

Part I

The amount of an improver or bleacher necessary to effect optimum results on a flour is very small and in consequence it might be expected that the amount of oxygen absorbed by flour during ageing would also be very small. The first experiment was therefore made with the object of ascertaining the magnitude of this absorption as on this would depend the technique to be employed in later work.

Some English wheat was freshly ground and a small sample was placed in a glass vessel closed with a rubber stopper but connected through the stopper to a mercury manometer the other end of which was open to the air. The whole, except the open end of the manometer, was immersed in a water bath at 25° C. At intervals of a few days the manometer reading was taken together with the barometric pressure. Any decrease in pressure (p) inside the absorption vessel is given by the formula:

$$p = (m_x - m_1) - (p_x - p_1),$$

where m_1 and p_1 are the manometric and barometric readings on the first day and m_x and p_x the corresponding readings after x days.

The curve in Figure 1 shows the decrease in pressure which took place during 60 days' storage. Since absorption of oxygen is reflected in a decrease in pressure the curve shows that for about the first 15 days there was apparently no such absorption. This was followed by a rapid absorption which ceased on the 38th day.

In the second experiment, four large flasks were nearly filled with flour, Nos. 1 and 2 with a sample of Manitoba and Nos. 3 and 4 with a sample of English. In flasks 2 and 4 tubes containing solid caustic soda were placed to absorb any carbon dioxide given off during storage. Each flask was connected to a mercury manometer the other end of which was connected to a small sealed glass bulb to eliminate the effects of changing atmospheric pressure on the manometer reading.

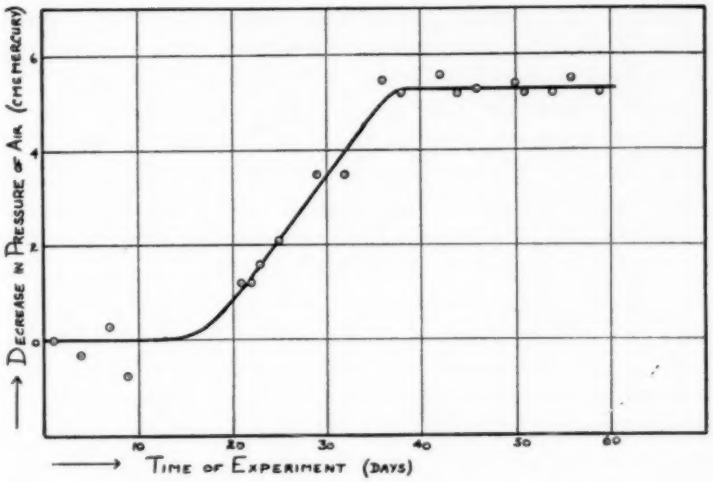


Figure 1. Decrease in pressure of air over flour during storage in sealed container.

Graphs showing the decrease in pressure with time inside these flasks are shown in Figure 2. With each flask of flour several days

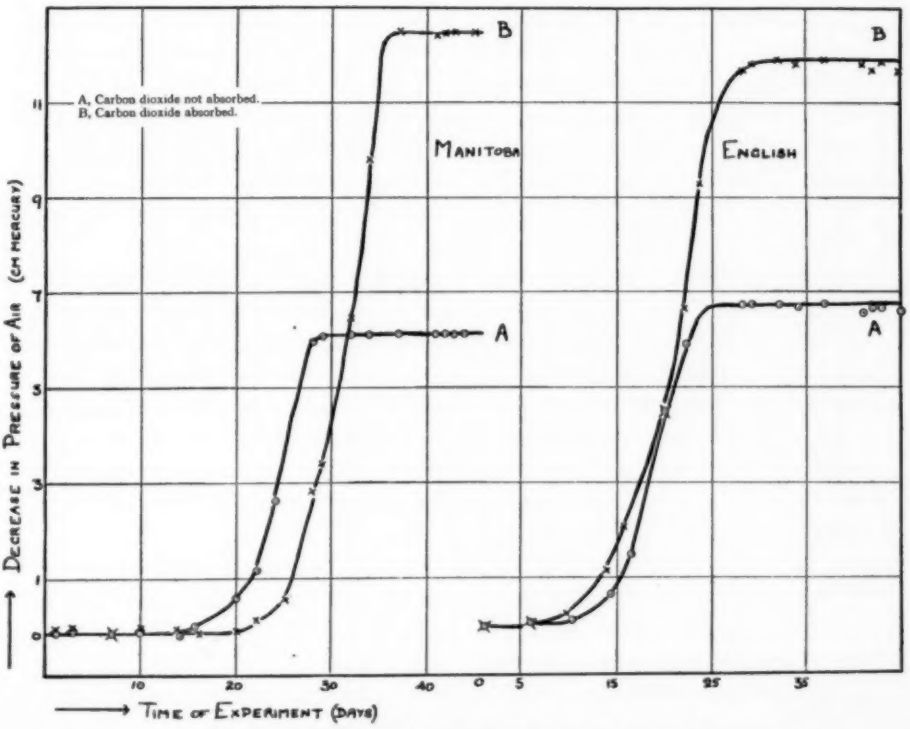


Figure 2. Effect of removal of CO_2, produced during storage, on decrease in pressure of air over flours in sealed containers.

elapsed before any change in pressure took place, then in each case a rapid but steady diminution occurred over a number of days, after which the pressure suddenly became and remained constant.

The observed total changes in pressure in the four flasks were No. 1, 6.2; No. 2, 12.7; No. 3, 6.7, and No. 4, 11.9 cm. of mercury. The atmospheric pressure on the day when the experiment was commenced was not noted but if the average figure of 76 cm. of mercury is taken the above changes in pressure correspond to the following changes in volume of air:

No. 1, 8.2%; No. 2, 16.7%; No. 3, 8.3%; No. 4, 15.6%.

The changes in volume of air in flasks 2 and 4 in which any carbon dioxide gas evolved was absorbed by the caustic soda present were not far removed from 20% of the total volume, which represents the total oxygen content of the air. When the absorption apparatus was constructed such large absorptions were not anticipated, and the bulbs at the end of the manometers were only small. This introduced an error into the readings such that the observed decreases in air pressure and volume were lower than those that actually occurred and since the bulbs were not all of the same size the error was not the same for each flask. Taking this into consideration it is justifiable to assume that the sudden cessation of absorption in the flasks was due to the complete absorption of the oxygen from the enclosed air.

The decreases in volume in flasks 1 and 3 were approximately half those in flasks 2 and 4. It appears that absorption of oxygen by flour is accompanied by the production of carbon dioxide and that the amount of carbon dioxide evolved is approximately half that of the oxygen absorbed.

The evolution of carbon dioxide suggests strongly that an important factor in oxygen absorption by flour is biological and that this factor is not bacterial but is associated with larger organisms such as mites which, like all other animals, breathe in oxygen and breathe out carbon dioxide. It is known that with many animals similar to mites there is no strict equivalence between oxygen intake and the output of carbon dioxide. Thus, with some organisms oxygen is stored up in various forms in the animal's body; in some insects, for example, calcium carbonate is a storage product.

With the object of throwing light on the question as to how far the oxygen absorption of flour is due to biological action and how far to chemical action a third series of experiments was commenced.

A freshly milled sample of English flour was divided into three lots and placed in absorption flasks. In one flask a little chloroform and toluene was added to prevent biological action and in another flask part

of the air over the flour was replaced by coal gas. Coal gas contains ethylene which in some cases acts as a pro-oxygen and so in such cases should speed up any oxidation due to chemical action. The third flask of flour served as a control.

The curves in Figure 3 show the progress of oxygen absorption as revealed by the diminishing pressure inside the absorption vessels.

All three samples showed a very slow and similar initial absorption, lasting for approximately 20 days in the control sample and that in contact with coal gas. This slow absorption was continued in the chloroform-toluene sample for 60 days when the experiment was stopped. With the control sample there was a rapid absorption after the 20th day

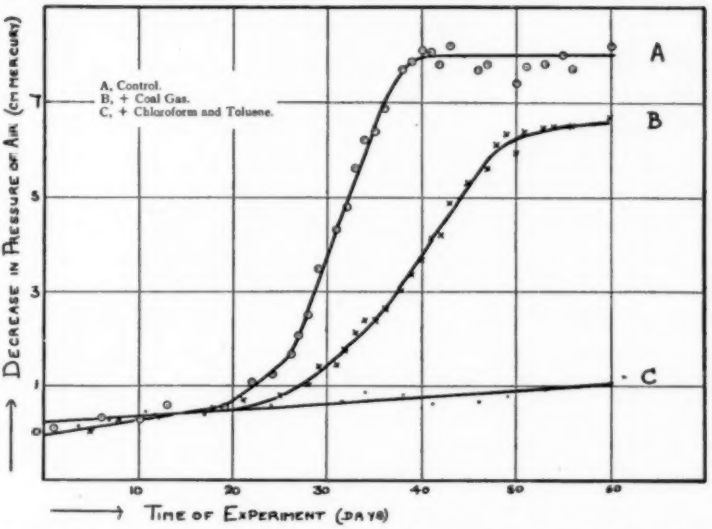


Figure 3. Effect of coal gas and of antiseptics on decrease in pressure of air over flours during storage in sealed containers.

which ceased on approximately the 40th day. In the sample in contact with coal gas there was a rapid absorption, although somewhat slower than in the control, and this ceased on approximately the 55th day.

The decreases in pressure inside the absorption vessels were 10.2% in the control sample, 8.9% in that in contact with coal gas, and 1.1% in that in contact with chloroform-toluene.

In this series of experiments the carbon dioxide evolved was not absorbed but, applying the results of the previous series of tests, the above decreases in pressure correspond to decreases in volume of 20.4% and 17.8% respectively for the control sample and that in contact with coal gas. Since, in the latter case, part of the air had been replaced by coal gas the oxygen content was reduced probably to the 17.8% at which absorption ceased.

The results of this series of tests suggest that two types of oxygen absorption can occur in flour, one very slow which proceeded at a uniform rate from the beginning to beyond the end of the experiment, and a second which only commenced after several days' storage, which was very rapid and which ceased when all the available oxygen was exhausted. This second type of absorption was prevented by chloroform-toluene and is undoubtedly of a biological nature.

Chloroform, however, can act as an anti-oxygen inhibiting oxidation but the addition of a small quantity of alcohol may prevent this. Toluene does not act as an anti-oxygen. In view of the possibility of the chloroform having acted as an anti-oxygen, a further series of experiments was made using a chloroform-alcohol mixture and also toluene alone. The results were similar to those just described and strengthened the suggestion that the rapid oxygen absorption prevented by the addition of these substances is of a biological nature.

Determinations of hydrogen ion concentration were made on the three samples of flour at the end of the experiment and yielded the following pH values: control flour 5.92, flour and coal gas 5.99, flour and chloroform-toluene 6.12. These results show that the larger absorptions of oxygen were accompanied by a considerable development of acidity.

The slow absorption of oxygen not prevented by the addition of chloroform could have been due to chemical auto-oxidation or possibly to some enzyme activity. In order to throw light on this a new series of experiments was commenced with the object of ascertaining whether during this slow absorption there was any production of carbon dioxide.

A sample of freshly milled commercial flour was divided into three lots, one served as a control and to the other two a few drops of chloroform were added. A tube of solid caustic soda was placed in the absorption flask containing one of the chloroformed samples. The curves in Figure 4 show the course of the changes in pressure inside the three absorption flasks.

The control sample showed the same behaviour as in the previous experiments, the slow absorption lasting for several days being followed by the rapid absorption which only ceased when the oxygen supply was exhausted.

The sample in the flask which contained chloroform but not caustic soda showed the same slow absorption as the control sample during the first 22 days but in this case the same rate of absorption was continued for 80 days when the experiment was stopped.

In the flask containing chloroform and caustic soda the initial rate of decrease in pressure was greater than in the other two flasks but after approximately 30 days the rate had decreased until it was even lower than in the case of the other chloroform sample.

At the end of the experiment the moisture contents of the three samples of flour were found to be 15.5%, 15.5%, and 10.1%. The last was that of the flour in the flask containing caustic soda, thus showing that there had been an exchange of water vapour between this sample of flour and the caustic soda.

This explains the difference in shape of the curves for the two chloroform samples. Owing to the rapid drying out of the flour by the caustic soda there was during the first 30 days a more rapid decrease in pressure due to the diminishing vapor pressure of the flour moisture

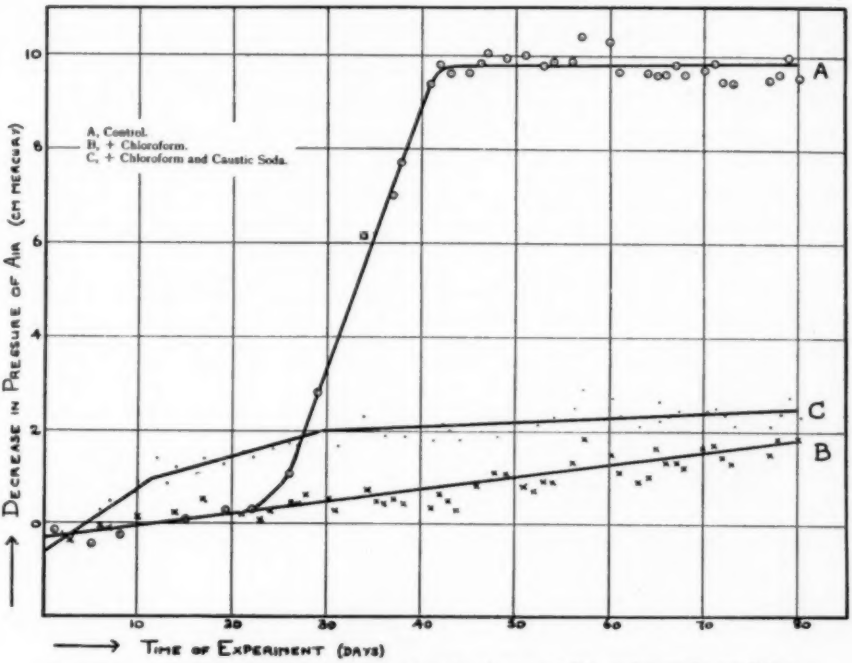


Figure 4. Decrease in pressure of air over flour in absence of CO_2 under sterile conditions.

and also possibly due to absorption of any carbon dioxide evolved. After 30 days the rate of oxygen absorption is slowed down, presumably owing to the flour having been dried out to an equilibrium value of about 10% moisture. At 30 days there was a difference in pressure between the two flasks containing flour in contact with chloroform of 1.5 cm. of mercury. The difference in vapour pressure over flour at 15.5% and 10% moisture is approximately 0.5 cm. of mercury. It follows that the decrease in vapour pressure does not wholly acount for the difference in pressure inside the two flasks. It therefore seems likely that there is some production of carbon dioxide during the slow absorption of oxygen by flour in the presence of chloroform vapour.

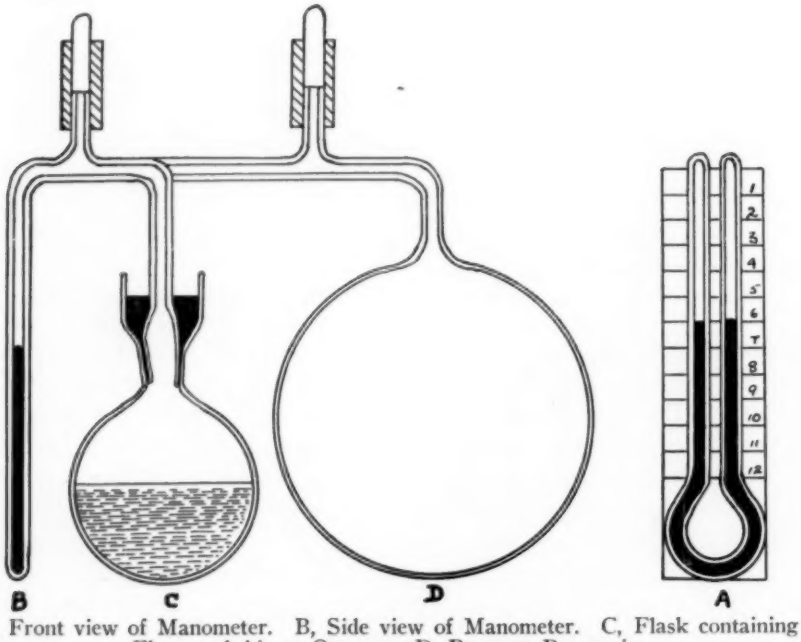
Part II

The experiments described in Part I suggest that two types of oxygen absorption occur in flour, one very slow which proceeds at a uniform rate, and a second which commences only after several days, which is very rapid and which ceases only when all the available oxygen is exhausted. The second type of rapid absorption is prevented by chloroform and is undoubtedly of biological nature. It is probably caused by larger organisms such as mites. Mites and their eggs are killed at 60° C.

To eliminate this factor and to accelerate the slower oxidation various series of experiments were carried out in an improved apparatus at 60° C., in addition to other series at 25° C. The apparatus was made entirely of glass, *i.e.*, with no corks or rubber connections, to enable the measurement of pressure changes to be made with greater precision. After the flour, etc., had been placed in the flask and the air displaced with oxygen, the apparatus was sealed and then immersed in water at the temperature desired throughout the experiment.

The apparatus is shown diagrammatically in Figure 5.

For the first of these tests made at the higher temperature two flours were used, a 35% patent and a 65% low-grade both milled from the same grist.



A, Front view of Manometer. B, Side view of Manometer. C, Flask containing Flour and Air or Oxygen. D, Pressure Reservoir.

Figure 5. Apparatus used for measurement of absorption of oxygen by flour.

Six absorption flasks were used, each containing the equivalent of 50 g. of flour at 15% moisture. Four contained the low grade flour: one of these served as a control, a second contained a tube of 20% caustic soda solution to absorb any carbon dioxide evolved, a third contained a few drops of chloroform to prevent any possible biological action due to mites, *etc.*, and the fourth contained both chloroform and a tube of 20% caustic soda. The fifth flask contained a sample of the low grade flour which had been dried to 10% moisture content together with a few drops of chloroform and a tube containing solid

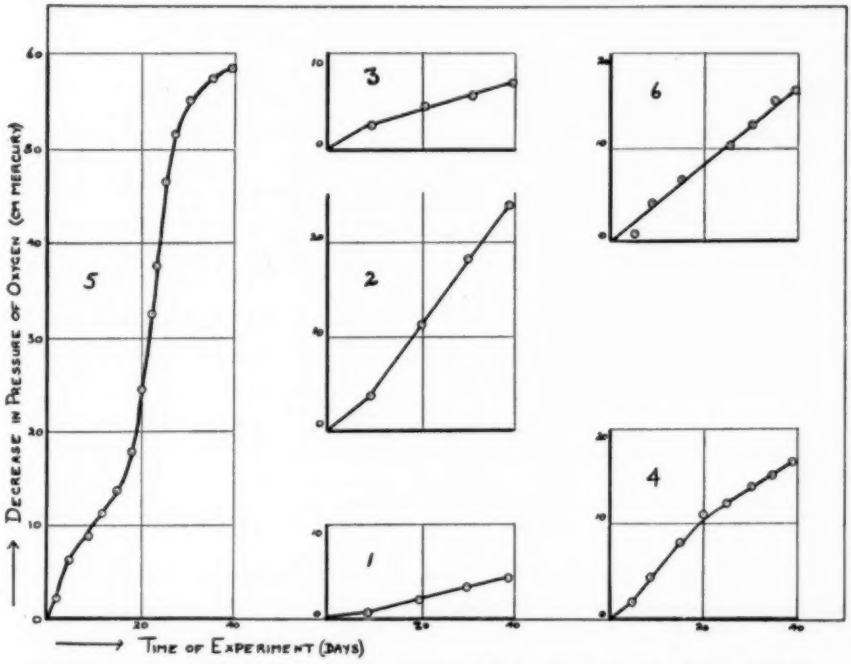


Figure 6. Decrease in pressure of oxygen over flours stored under various conditions at 60° C. (see Table I).

caustic soda. The sixth flask contained the patent flour together with chloroform and a tube of 20% caustic soda.

The original pressure of the oxygen inside the flasks was equivalent to 76.1 cm. of mercury. The changes in pressure with time are shown in Figure 6.

At the end of the experiment, which lasted for 39 days, the flours were analysed for moisture, hydrogen ion concentration, fat content, and iodine value of the extracted fat. The results obtained are given in Table I which also includes the analysis of the flours before storage.

An examination of the absorption curves shows that the decrease in pressure in flasks 1 and 3 was very little, amounting to only 5 to 7

cm. mercury, while in flasks 2, 4, and 6 the decreases varied from 16 to 19 cm. mercury, and in flask 5 to 58 cm. mercury.

Flask 5 contained flour originally at 10% moisture but owing to the presence of solid caustic soda the moisture content was reduced to 4.1% at the end of the experiment, while in flasks 2, 4, and 6 the flours originally at approximately 14.5% moisture had their moisture contents increased to approximately 19% due in this case to the presence of 20% caustic soda solution.

The fact that the control sample in flask 1 absorbed so little oxygen suggests that the biological changes that take place in flour exposed to

TABLE I

ANALYTICAL DATA ON FLOURS STORED UNDER VARIOUS CONDITIONS IN OXYGEN AT 60° C. FOR 39 DAYS

	Flask	Oxygen absorbed[1] %	Moisture content %	pH	Fat %	Iodine value of fat
				On a 15% moisture basis		
Low grade before storage	—	—	14.5	6.14	1.08	113
Low grade after storage:						
Control	1	5.0	14.4	5.53	0.97	111
+ tube of 20% caustic soda	2	31.5	19.5	5.17	0.79	106
+ tube of chloroform	3	9.4	14.4	5.52	1.05	105
+ 20% caustic soda and chloroform	4	22.3	18.7	5.32	0.99	99
Previously dried to 10% moisture: + solid caustic soda and chloroform	5	76.7	4.1	5.54	0.44	52
Patent before storage	—	—	14.7	5.80	0.77	107
Patent after storage + 20% caustic soda and chloroform	6	21.5	19.5	5.13	0.67	76

[1] Assuming that there is no evolution of CO_2 and that therefore the per cent. oxygen is proportional to the pressure inside the absorption flasks.

air at 25° C. are inhibited at 60° C. due presumably to mites being killed at this higher temperature.

The sample of dry flour in flask 5 changed in hydrogen ion concentration no more than the control sample but its fat content and the iodine value of the fat were reduced by more than 50% suggesting that the relatively high absorption of oxygen in this case was due to true chemical oxidation.

The flours in flasks 2, 4, and 6 with high final moisture contents showed the greatest production of acidity. Of these three samples the patent flour in flask 6 showed a decrease of more than 25% in the iodine value of its fat. The iodine values of the fat extracted from the low grade flour in flasks 2, 3, and 4 showed reductions of from 6% to 12%.

The results of these tests indicated that the oxygen absorption observed was true chemical auto-oxidation largely of the fat present in flour and that the rate and course of oxidation are largely controlled by the moisture content of the flour.

To throw further light on the problem a further series of tests was made at 60° C. In this case five samples of the same flour were used but with moisture contents varying from 6% to 20%. Each absorption flask contained the equivalent of 50 g. of flour at 15% moisture. The course of absorption as shown by the decreasing pressure inside the flasks is given by the curves in Figure 7.

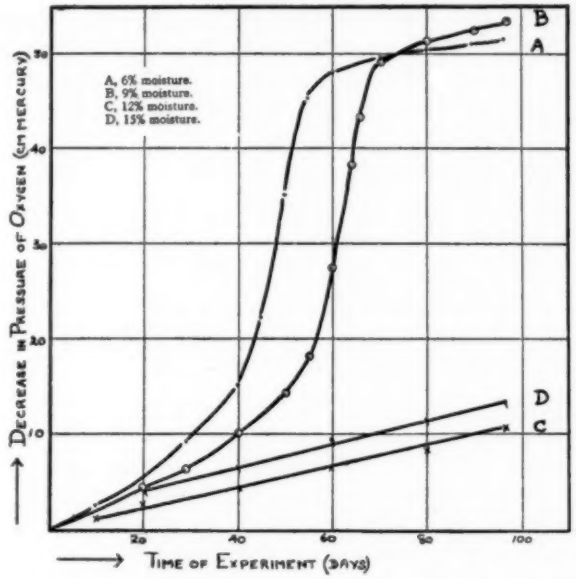


Figure 7. Effect of varying moisture content on oxygen absorption by flour at 60° C.

At the end of the experiment, which lasted for 97 days, the flours were analysed as in the first series and the results obtained are given in Table II.

During the course of the experiment the flours with 6% and 9% moisture both absorbed a considerable percentage of the oxygen in the

TABLE II

Analytical Data on a Flour Stored at Different Moisture Contents in Oxygen at 60° C. for 97 Days

	Moisture content %	pH	Fat %	Iodine value of fat
		On a 15% moisture basis		
Before storage	13.94	5.86	1.14	110
6% after storage	6.71	5.09	0.36	45
9% after storage	9.41	5.06	0.43	47
12% after storage	12.02	5.33	1.05	105
15% after storage	14.91	5.01	0.95	111
20% after storage	20.7	4.66	0.24	43

flasks. This absorption was accompanied by a lowering of the extractable fat from 1.14% to 0.36% and 0.43% respectively, and a lowering of the iodine value of the extracted fat from 110 to 45 and 47 respectively.

The flours with 12% and 15% moisture absorbed much smaller quantities of oxygen, and in these cases the percentages of extractable fat and its iodine values were only slightly affected.

In the case of the flour with 20% moisture the absorption of oxygen during the first 12 hours was so rapid that the mercury was sucked from the manometer and no pressure readings could be taken the following day; however, the low yield of extractable fat with its low iodine value indicated that very considerable absorption took place.

These tests indicated that oxidation at 60° C. takes place most readily with flours of abnormally low and abnormally high moisture contents and that absorption is accompanied by an oxidation of the flour fat.

The next series of tests was made with the object of ascertaining how far the fat content of flour was responsible for oxygen absorption at 60° C. The flour used was the same as in the previous tests, six samples being used, two at approximately 6% moisture, two at 12% moisture and two at approximately 18% moisture. One of each pair of flour samples had been ether extracted to remove the fat.

In this series the flasks only contained the equivalent of 25 g. flour at 15% moisture. The experiment was carried on for 128 days.

The absorption curves on these flours are given in Figure 8 and the results obtained from their analysis in Table III.

TABLE III

ANALYTICAL DATA ON A FLOUR, NORMAL AND ETHER-EXTRACTED, STORED AT DIFFERENT MOISTURE CONTENTS IN OXYGEN AT 60° C. FOR 128 DAYS

	Colour at end of experiment	pH	Fat %	Iodine value	Oxygen absorbed[1] %
		On a 15% moisture basis			
Unextracted flour					
5.9% moisture	Deep cream	4.94	0.31	33	38.2
12% moisture	Very deep cream	4.96	0.42	37	29.2
17.8% moisture	Coffee coloured	4.74	0.28	42	35.9
Extracted flour					
5.9% moisture	White	5.60	0.04	17	10.8
12% moisture	White, but with a slight tinge of brown	5.49	0.05	35	2.0
17.8% moisture	A shade lighter than "unextracted 17.8%"	4.76	0.09	23	16.1

[1] Original pressure of oxygen = 74.3 cm. Hg.

The curves for the unextracted samples illustrate the effect of moisture on absorption. The flour with 18% moisture absorbed oxygen rapidly during the first few days after which the rate decreased rapidly

and reached a steady state which persisted until the end of the experiment. The flour with only 6% moisture had, on the other hand, only a slow absorption to start with but the rate gradually increased and for a few days was very rapid after which it quickly fell off and, during the final period, was at the same slow, steady rate as in the case of the flour with 18% moisture. The rate of absorption of the flour of 12% moisture was very slow for a considerable time and then gradually increased to a maximum afterwards falling off again, the final rate being the same as with the other two flours.

In this series of tests the flour of 12% moisture commenced to increase its rate of oxygen absorption after about 60 days, while in the

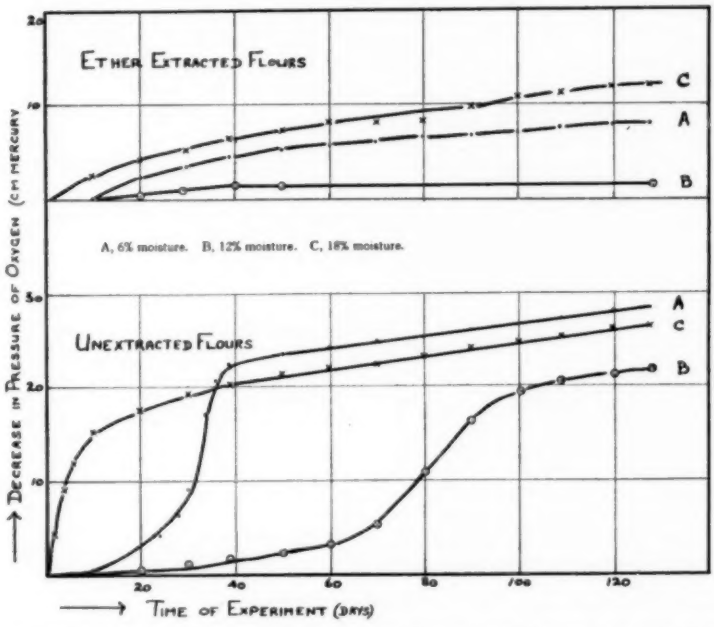


Figure 8. Effect of ether extraction and moisture content on oxygen absorption by flour at 60° C.

previous series, using the same flour at the same moisture content, the rate was still slow after 97 days when the experiment was stopped. Also in this series the flour of 6% moisture attained its rapid rate of absorption after about 30 days compared with about 40 days in the previous series. Between the two series of tests the flour had been stored for about 4 months in winter weather and, judging from the very slight change in hydrogen ion concentration, had not altered appreciably. However, the apparent induction period prior to rapid absorption appeared to have decreased during storage.

The pH of all three unextracted flours dropped during the experi-

ment to under 5; the fat contents decreased by over 60% and the iodine value of the fat also decreased by over 60%.

The extracted flours were not absolutely fat free, as can be seen from the data in Table III, the amounts left in the flour varying from 0.04% to 0.09%. The rates of oxygen absorption were much lower and more regular than those of the unextracted samples which suggest that the fat content of the unextracted flour was chiefly responsible for the large absorption taking place with these flours.[2]

For comparison with the oxygen absorption of flour at 60° C. a final series of tests was made using flour at 0%, 5%, and 18% moisture,

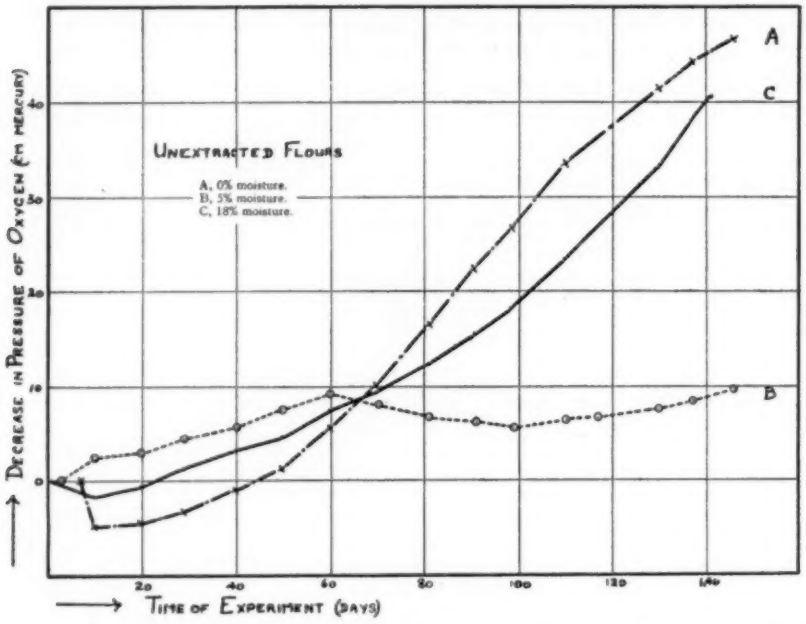


Figure 9. Effect of ether extraction and of moisture content on oxygen absorption by flour at 25° C. (Control for data in Figure 10.)

both ether-extracted and unextracted, and storing them in the apparatus in an atmosphere of oxygen at 25° C.

The flour used was a freshly milled sample of Australian and each absorption flask contained the equivalent of 50 g. of flour at 15% moisture. A small open tube of chloroform was placed in each sample to prevent biological activity of mites, *etc.*

Curves showing the changes in pressure inside the flasks during the experiment are given in Figures 9 and 10 and analytical data on the flours after storage in Table IV.

During the first 10 days the reduction in pressure inside the flasks

[2] The possibility of the effect being due to some direct action of the solvent (ether) on some other oxygen absorbing constituent (possibly biological) cannot be entirely ruled out.

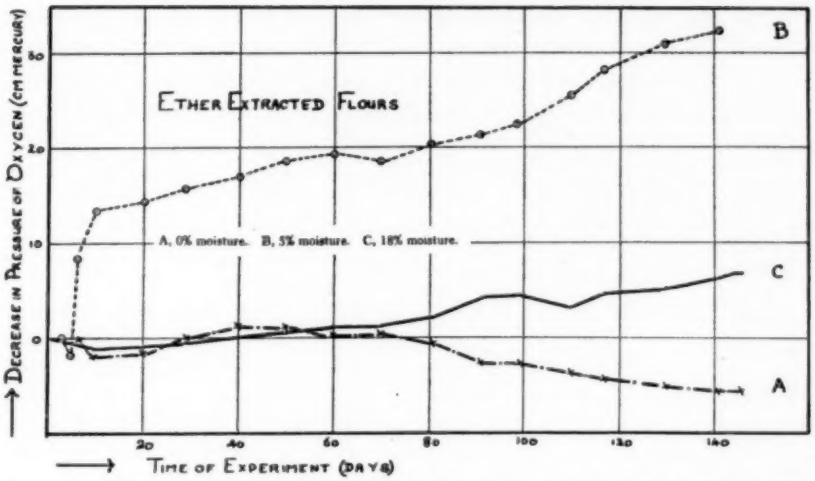


Figure 10. Effect of ether extraction and of moisture content on oxygen absorption by flour at 25° C.

was, with each of the six samples of flour, irregular compared with the general changes in pressure after 10 days. These irregularities were possibly caused by the presence of the chloroform. If an open tube of chloroform is placed inside a vessel containing flour and the whole sealed up the chloroform gradually disappears from the tube by evaporation and absorption by the flour of the chloroform vapour. The

TABLE IV

ANALYTICAL DATA ON A FLOUR, NORMAL AND ETHER-EXTRACTED, STORED AT DIFFERENT MOISTURE CONTENTS IN OXYGEN AT 25° C. FOR 146 DAYS

	pH	Fat %	Iodine value of fat
	On a 15% moisture basis		
Unextracted flour			
0% moisture	4.97	0.31	41
5% moisture	5.64	0.91	77
18% moisture	5.33	0.44	58
Extracted flour			
0% moisture	5.43	0.08	48
5% moisture	5.47	0.04	—
18% moisture	5.82	0.17	71

Pekar Slide. Unextracted (0% moisture) had a slight brown tinge. All the others were dead white, there being no difference between the extracted and unextracted samples.

tube can be refilled several times with chloroform before absorption ceases. This was very apparent in the experiments reported later in Part III. An effect which was probably due to this is shown up by plotting curves relating the acid value of the fat with time of storage. In the case of the control, heat-treated, and dry flours the curves are straight lines but with the chloroform sample the curve gradually bends over showing that the effectiveness of the chloroform in inhibiting

changes in the flour increased as the flour became more and more saturated with chloroform vapour.

The pressure inside a vessel containing both flour and a tube of chloroform would not become steady until absorption of the chloroform vapour by the flour ceased and any abrupt changes, such as the complete disappearance of chloroform from the tube, might cause abrupt changes in pressure also.

This is a probable explanation of the erratic changes in pressure inside the absorption flasks in this series of tests.

With the unextracted flours (see Figure 9) the pressure decreased in each case at approximately the same rate between the 10th and the 60th days. After this the pressure in the flask with flour at 5% moisture showed no further decrease, while in the other two cases the decrease in pressure continued until the experiment was stopped on the 146th day.

The flour of 5% moisture which absorbed least oxygen also showed the least change in its fat content, 0.91% fat with an iodine value of 77 being obtained at the end of the experiment, while in the case of the flour of 0% moisture only 0.31% fat with an iodine value of 41 was obtained.

This absorption of oxygen is therefore obviously due to chemical auto-oxidation of the fat, the course of oxidation being largely controlled by the moisture content of the flour.

The extracted flours were not quite fat free and some absorption of oxygen took place. Apart from the rapid and unexplained absorption between the 5th and 10th days of the sample of 5% moisture content there was little difference in absorption rates between the three samples.

The results indicate that oxygen absorption by flour under conditions which prevent the activities of larger organisms such as mites is due primarily to the fat content of flour, and that the rate of absorption is greatest in flours of very low and of very high moisture contents. There is some intermediate moisture content, which appears to be in the neighbourhood of 12%, at which rate of oxidation is at a minimum. It is known that moisture acts as an inhibitor of oxygen absorption by fatty substances, possibly through the formation of a protective water film over the reacting material. The decreasing rate of oxygen absorption with increasing moisture content of flour up to 12% is therefore explicable. The increasing rate of oxygen absorption at moisture contents above 12% may be due to bacterial activity which, over a range, is known to increase with increasing moisture content. Bacteria and fungi in material such as flour can be completely suppressed by chloroform but no bacterial or fungal counts were carried out and it is not

possible to say whether the flour under the conditions of this experiment was effectively sterilised.

There appear therefore to be three main factors determining the absorption of oxygen by flour when stored in *pure oxygen:*

(1) Mites or other small animals, which like all animals breathe in oxygen and breathe out carbon dioxide. (This factor can be suppressed by raising the temperature to 60° C., or by reducing the moisture content to below 12%, or by the presence of chloroform.)

(2) Bacteria and fungi which become active at higher moisture contents than, say, 12%. (These organisms are not killed by raising the temperature to 60° C. although they may be completely suppressed by chloroform.)

(3) Chemical auto-oxidation of flour fat. (This process becomes progressively more rapid as the moisture content of the flour is reduced below 10 or 12%, and which presumably is most rapid at zero moisture content.)

Part III

In June 1932 a bag of commercial flour of 73% extraction and freshly milled from a grist consisting of 10% Australian, 10% English, and 80% Barusso Plate wheat was divided into four samples which were subsequently kept in large tins. This was the same flour as was used in the first two series of experiments described in Part II.

One sample, with a moisture content of 15%, was used as a control, a second was dried to approximately 10% moisture, a third was heat-treated, and with the fourth a tube of chloroform was placed in the containing tin. The moisture content of the heat-treated sample was adjusted by spraying.

At fortnightly intervals the tins were opened and the flours examined for gluten content, hydrogen ion concentration and buffer value, fat content and iodine and acid values of the fat. The analytical results so obtained are given in Tables V to VIII. At monthly intervals the samples were baked.

A summary of the baking tests is as follows:

Before Storage: The flour was baked with the addition of 0.1% malt extract and 0.05% ammonium phosphate to ensure adequate gas production, which additions were used in all subsequent bakings.

With 16 gallons of liquor per sack the dough had fairly good body with good extensibility and fairly good spring. It behaved well during fermentation. The bread had good volume and good outside appearance. The crumb of the cut loaf had good grain and very good texture

TABLE V

ANALYTICAL DATA ON FLOUR STORED IN AIR-TIGHT TINS

Control Sample

Time in weeks	Moisture %	Dry gluten %	pH	Buffer value	Fat %	Iodine value of fat	Acid value of fat
0	14.96	10.5	6.11	0.73	0.95	112	11
2	14.82	10.9	5.97	0.68	0.98	110	19
4	14.91	10.9	6.06	0.76	0.99	112	17
6	14.74	10.7	5.99	0.75	0.97	112	20
8	14.85	10.8	5.82	0.66	0.99	111	23
10	14.71	10.6	5.63	0.58	0.91	115	27
13	14.95	9.9	5.25	0.45	0.86	114	31
15	15.12	10.0	4.95	0.36	0.79	116	34
17	14.81	9.8	4.65	0.26	0.67	116	34
19	14.77	9.2	4.43	0.26	0.56	124	34
28	15.23	8.7	4.22	0.14	0.42	110	67

N.B.—All determinations expressed on a 15% moisture basis.

TABLE VI

ANALYTICAL DATA ON FLOUR STORED IN AIR-TIGHT TINS

Heat-treated Sample

Time in weeks	Moisture %	Dry gluten %	pH	Buffer value	Fat %	Iodine value of fat	Acid value of fat
0	13.73	10.7	6.07	0.68	1.01	108	9
2	13.45	10.8	6.06	0.72	1.00	109	12
4	14.23	10.7	6.04	0.73	1.01	108	13
6	13.99	10.7	5.97	0.70	0.98	111	18
8	14.00	10.9	5.94	0.69	1.01	109	18
10	13.95	11.0	5.91	0.66	0.97	112	20
13	14.15	10.5	5.89	0.60	0.97	114	22
15	14.23	10.8	5.95	0.70	0.97	113	24
17	13.91	10.7	5.93	0.69	0.98	107	25
19	13.94	10.8	5.81	0.61	0.94	114	28
28	14.17	10.0	5.02	0.37	0.79	116	31

N.B.—All determinations expressed on a 15% moisture basis.

TABLE VII

ANALYTICAL DATA ON FLOUR STORED IN AIR-TIGHT TINS

Dry Sample

Time in weeks	Moisture %	Dry gluten %	pH	Buffer value	Fat %	Iodine value of fat	Acid value of fat
0	—	—	—	—	—	—	—
2	9.86	10.9	6.08	0.74	0.95	111	11
4	10.05	11.0	6.12	0.75	0.95	113	12
6	9.95	10.8	6.10	0.82	1.00	106	13
8	10.06	10.7	6.05	0.75	0.97	110	14
10	9.89	11.1	6.05	0.76	0.99	111	15
13	10.17	10.6	6.06	0.73	0.96	111	17
15	10.23	11.0	6.12	0.78	0.98	110	18
17	9.81	10.8	6.08	0.76	0.98	106	19
19	10.00	11.1	6.08	0.74	0.98	110	19
28	10.19	11.0	5.95	0.64	0.98	112	23

N.B.—All determinations expressed on a 15% moisture basis.

and spring. The colour was a rather deep cream with very good bloom. In general it handled and baked out as a good sample of commercial flour milled from a mixed grist. Sum of loaf perimeters equalled 50¼ inches.

TABLE VIII

ANALYTICAL DATA ON FLOUR STORED IN AIR-TIGHT TINS

Chloroform Sample

Time in weeks	Moisture %	Dry gluten %	pH	Buffer value	Fat %	Iodine value of fat	Acid value of fat
0	14.96	10.5	6.11	0.73	0.95	112	11
2	15.00	10.7	6.04	0.74	0.98	110	14
4	15.19	10.8	6.05	0.76	1.00	109	15
6	15.09	10.7	6.02	0.75	1.02	106	17
8	14.92	10.7	5.93	0.69	0.98	112	18
10	15.00	11.0	5.91	0.68	0.97	113	19
13	15.34	10.3	5.93	0.67	0.98	112	20
15	15.46	10.5	5.95	0.69	0.97	114	22
17	14.81	10.5	5.90	0.63	0.97	108	23
19	14.72	10.7	5.88	0.63	0.96	114	24
28	15.17	10.4	5.87	0.64	0.94	117	24

N.B.—All determinations expressed on a 15% moisture basis.

ONE MONTH OLD: All four samples were baked when they were one month old. With 16 gallons of liquor per sack they all made good bodied doughs which behaved satisfactorily as fermentation progressed. Apart from the chloroform samples they made loaves of similar good volume, outside appearance, and satisfactory crumb. The loaf from the chloroform sample was rather smaller.

The loaf perimeters were:

Control	48	inches
Dry	47¾	"
Heat-treated	47	"
Chloroform	45¼	"

TWO MONTHS OLD: When two months old the control, heat-treated, and chloroform samples made fairly tough and rather short doughs. The dry sample made a more tender dough with better extensibility. All behaved well during fermentation.

The dry sample baked out with excellent volume and outside appearance and the crumb was very soft.

The other three samples made rather smaller loaves, although still of very good volume, with good outside appearance except for some tearing on the sides. Their crumbs were also less soft and of closer grain than was the case of the dry sample.

Loaf perimeters:

Control	49	inches
Dry	51⅛	"
Heat-treated	50	"
Chloroform	50⅜	"

FOUR MONTHS OLD: The dry sample again made the most tender dough the others being tougher and rather short. During fermentation, they all fell off somewhat unduly and moulded rather tenderly. When baked the control made a small loaf with ragged sides. The crumb was tough and rubbery and appeared waterlogged.

The heat-treated and chloroform samples made loaves with good volume and outside appearance. The crumbs were also good. The chloroform sample had a bleached appearance.

The dry sample made an excellent loaf with good volume and outside appearance and good crumb.

Loaf perimeters:

Control	44¼ inches
Dry	51 "
Heat-treated	48⅞ "
Chloroform	50⅞ "

During four months' storage at 25° C. the control sample had therefore badly deteriorated, the heat-treated and chloroform samples had changed comparatively little, and the dry sample had improved in baking quality.

Photographs of the four loaves are shown in Figure 11.

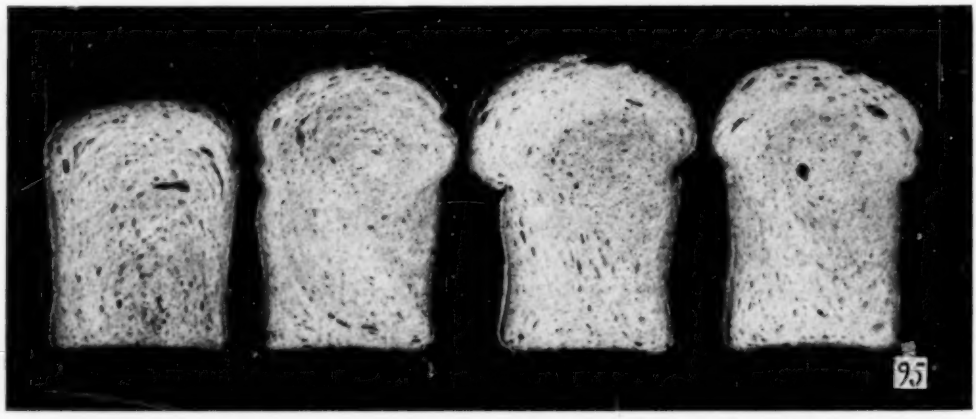


Figure 11. Left to right: Loaves made from normal flour, heat-treated flour, flour dried to 10% moisture, and flour stored in presence of chloroform. All after 4 months' storage.

The changes in analytical figures that accompanied the changes in baking quality are given in Tables V to VIII. The most striking change is in acidity, the pH of the control sample decreasing by as much as 1.47 in 17 weeks, while in the same time the corresponding changes in the heat-treated and chloroform samples were only 0.14 and 0.21 respectively. During the same period the dry sample showed no significant change in pH.

The large production of acidity in the control sample accounts for the drop of about 1% in dry gluten; the amount of gluten washed from the other samples showed no change during storage. The increased acidity also accounts for the considerable drop in buffer value of the control sample from 0.73 to 0.26.

In the control sample there was also a drop in extractable fat from 0.95% to 0.67% but with the other samples there was no change in fat content up to 20 weeks.

The acidity of the fat from the control sample increased in 17 weeks from 11.0 to 33.8 an increase of 22.8 units; the corresponding increases for the heat-treated, chloroform, and dry samples were 15.9, 11.9, and 7.5 units respectively.

The iodine values of the fats from all four samples did not change during storage.

It would appear from these results that the marked deterioration in flour due to prolonged storage is caused by biological agencies such as mites or related species and moulds or bacteria, and that when these agencies are suppressed by drying or by heat-treating the flour or by the presence of chloroform the flour may be kept for prolonged periods without serious deterioration.

Since iodine values of the fats extracted from all four samples did not change during storage, even in the case of the flour dried to 10% moisture, true chemical auto-oxidation of the fats probably did not occur. There are indications in Tables I and II that in oxygen the fat content and the iodine values of the fats changed only very little during storage when the moisture content of the flour was in the neighbourhood of 12% to 14%. At both higher and lower moisture contents there was great reduction in iodine values. In view of the facts that flour at 10% moisture stored in air showed no change in fat content or in iodine value for 28 weeks, while at 15% moisture it decreased by two-thirds in fat content without any change in iodine value, it seems likely that ordinary commercial flours of commercial moisture contents do not undergo chemical auto-oxidation during storage in air, the moisture present possibly forming a protective layer round the auto-oxidisable fatty constituents.

This apparent difference in the behaviour of flour as regards auto-oxidation when stored in oxygen and in air respectively is difficult to explain. Possibly the partial pressure of the oxygen is a factor in rate of auto-oxidation.

Summary

During storage many plant and animal products undergo changes. The changes taking place in milk and meat are due largely to bacterial action, but with butter, rubber, and linseed oil it is auto-oxidation by air which produces the observed changes. Cereal products also undergo similar changes during storage. Wheat meal and wheat germ, for example, become rancid on prolonged storage, and sour and musty flours are not unfamiliar to millers.

During storage of flour in normal circumstances the colouring matter of the flour is bleached and with some flours, if not with all, there is an improvement in baking quality as a result of storage. If storage is too prolonged marked deterioration in baking quality results.

To some extent the natural effects of age can be produced by means of bleaching agents and chemical improvers, a class of substances which are in general powerful oxidising agents. Because of this it has been generally assumed that the effects of age on flour are due to oxidation by atmospheric oxygen although there is little real evidence to justify the belief.

Flours of different kinds and of different moisture contents, untreated and treated in various ways, were stored in apparatus of special design, containing sometimes oxygen and sometimes air. Oxygen absorption was measured from day to day throughout the experiments and other effects of the storage were investigated by means of certain analytical tests. In some cases baking tests were also carried out.

The results of the investigation indicated that when flour is stored in air considerable absorption of oxygen occurs. The results can be explained on the assumption that there are three main factors determining the absorption of oxygen by the flour:

(1) Mites and similar small animals. (These feed on the flour and, like all other animals, breathe in oxygen and breathe out carbon dioxide. This factor can be suppressed by raising the flour to 60° C., or by reducing the moisture content of the flour to below about 12%, or by the presence of chloroform.)

(2) Bacteria and fungi which become active when the moisture content of the flour exceeds about 12%. (These organisms cause definite deterioration of flour including oxidation of flour constituents but only at moisture contents above about 12%. They cannot be killed by raising flour temperature to 60° C., but may be completely suppressed by the presence of chloroform. Their activities can be stopped also by drying the flour to below 12%.) Below about this moisture content a third oxidation factor becomes operative, *viz.* (3).

(3) True chemical auto-oxidation. (This process becomes progressively more rapid as the moisture content of the flour is reduced and is presumably most rapid at zero moisture content. It is known that moisture acts as an inhibitor of oxygen absorption by fatty substances, possibly through the formation of a protective water film over the reactive material.)

This chemical auto-oxidation of flour consists of oxidation of the fatty constituents of flour, which results in a diminution in the extractable fat content of the flour and in changes in chemical nature of the fat (*e.g.*, iodine value is lowered), and oxidation of the carotene which

has the additional effect of removing the yellow colour of the carotene and hence of the flour. The former type of auto-oxidation, *i.e.*, oxidation of fatty constituents, appears to occur only when flour is stored in oxygen. When flour is stored in *air*, as in ordinary commercial practice, the oxidation of flour fat does not apparently occur. Although the fat content diminishes, the iodine value of the fat is unaffected during many months of storage. However, oxygen (slight) absorption by carotene occurs as is shown by a bleaching effect.

This difference in behaviour of flour as regards auto-oxidation of fat when stored in oxygen and in air respectively is difficult to explain.

The implications of commercial interest arising out of this work are the following:

(1) The striking effect of heat treatment on the keeping quality of flour due to the partial sterilising action of the process. For this effect to be at a maximum it would be necessary to heat treat the whole flour stream and not only a portion of it as is customary when this treatment is employed as an improvement process.

(2) The rapid increase in biological activities in flour at moisture contents above about 12%, activities which increase further very markedly at higher temperatures. This emphasises the great importance of moisture content in flour intended for export to tropical or semi-tropical countries or for use in ships. Such flour cannot be exported with safety at moisture contents above 12%; below this it is not necessary to go.

It appears likely that the heat treatment of flour enables flour of a somewhat higher moisture content than 12% to be exported to warm countries without serious risk of deterioration.

Literature Cited

Anderegg, N. T., and Nelson, V. G.
1926 Milk powders as foods. II. Observations on the existence of Vitamin E. Ind. Eng. Chem., **18**: 620–622.
Emery, J. A., and Henley, R. R.
1922 Studies in rancidity. I. The influence of air, light and metals on the development of rancidity. Ind. Eng. Chem., **14**: 937–940.
Ferrari, C. G., and Bailey, C. H.
1929 Effect of storage and of various bleaching agents on the carotene concentration of flour. Cereal Chem., **6**: 457–482.
Fine, M. S., and Olsen, A. G.
1928 Tallowiness or rancidity in grain products. Ind. Eng. Chem., **20**: 652–654.
Greenbank, G. R., and Holm, G. E.
1924 Some factors concerned in the auto-oxidation of fats, with special reference to butter fat. Ind. Eng. Chem., **16**: 598–601.
1925 Measurement of susceptability of fats to oxidation. Ind. Eng. Chem., **17**: 625.
Kerr, R. H.
1918 Chemical tests for the detection of rancidity. Ind. Eng. Chem., **10**: 471–475.

Kreis, H.
1902 Mittheilungen aus der analytischen praxis. Ueber neue farben reaktionen fetter oele. Chem. Z., **26**: 1014.
Mattill, H. A.
1927 The oxidative destruction of Vitamins A and E. J. Am. Med. Assoc., **89**: 1505–1508.
1931 Anti-oxidants and the auto-oxidation of fats. J. Biol. Chem., **90**: 141–151.
Milas, N. A.
1932 Auto-oxidation. Chem. Rev. **10**: 295–364.
Moureu, C., and Dufraisse, C.
1926 Catalysis and auto-oxidation. Chem. Rev., **3**: 113–162.
Roller, P. E.
1931 Effect of wheat germ oil on the keeping quality of fats and food rations. J. Phys. Chem. **35**: 3286–3292.
Taffel, A., and Revis, C.
1931 The determination of rancidity of oils and fats. The Kreis test. J. Soc. Chem. Ind., **50**: 87T–91T.
Triebold, H. O.
1931 Rancidity. Cereal Chem., **8**: 518–532.
Triebold, H. O., and Bailey, C. H.
1932 Rancidity. Cereal Chem., **9**: 50–64; 91–106.
Triebold, H. O., Webb, R. E., and Rudy, W. J.
1933 Rancidity. Cereal Chem., **10**: 263–276.

THE RELATIVE MACARONI MAKING QUALITY OF A NUMBER OF DURUM WHEAT VARIETIES [1]

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(Read at the Annual Meeting, June 1936)

Introduction

The suitability of various durum wheat varieties for macaroni-making is a matter of considerable interest to both the miller of durum products and the plant breeder. The literature on this is very meagre and yields little specific information, although the relative quality of the standard varieties is well known in a general way. An excellent bibliography is given by Phillips and Shollenberger (1927) and a brief resumé of the agronomic, milling, and macaroni-making characteristics of the standard varieties may be found in the "Dictionary of Spring Wheat Varieties" (1933). The studies to be described were conducted in an effort to secure more detailed information not only upon the milling and macaroni-making characteristics but also on pigment content and other factors possibly associated with quality.

While material was available from only two crop years, the lack of specific information mentioned above appeared to warrant the publication of the data now available although the conclusions drawn can only be regarded as preliminary.

Materials and Methods

The wheats employed in this study were all experimentally grown and consist of four groups: (1) and (3) comprising thirteen samples each grown on 1/60th acre plots at the Dominion Experimental Station, Morden, Manitoba, in the years 1934 and 1935 respectively; (2) comprising five samples grown in 1935 at the University of Saskatchewan, Saskatoon, Saskatchewan, and (4) three samples grown in the same year at the Dominion Experimental Station, Swift Current, Saskatchewan. The Morden samples were grown for the Dominion Rust Research Laboratory as part of a plant breeding program for durum wheats. Official grades and weights per imperial bushel were secured on all samples which were then milled into semolina and processed into macaroni by the technique outlined by Binnington and

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Geddes (1936). Protein and carotene determinations were made on the wheats and semolinas by the official A. A. C. C. methods using the spectrophotometric procedure for the carotene determinations, all samples being ground in a Wiley mill fitted with a 1/2 mm. sieve. In addition, the macaroni produced was submitted to color analysis and cooking tests. The color analyses of the samples in group (1) were made with the original model N. A. Colorimeter and discs described by Baker *et al.* (1933), using a daylight lamp as illuminant. A single layer of macaroni broken into suitable lengths so as to completely fill the sample tray supplied with the instrument was used. In order to secure a uniformly neutral background, the bottom of the tray was fitted with several layers of filter paper, prior to inserting the macaroni. The filled tray was rotated in the usual manner.

The results of these color analyses are obtained as percentage of red, yellow, white and black discs and can be best expressed graphically as histograms. However, in earlier color studies made in this laboratory, the spectrophotometer was extensively employed and some method of relating the N. A. instrument results to the three conventional attributes of color, *i.e.*, hue, brilliance, and saturation, seemed desirable. This computation could be made if the Munsell values of the N. A. color discs were known, but at the time these initial studies were made these data were not available and the following method for securing some approximation to the desired values was accordingly developed. The ratio of % yellow to % red is taken as an indication of "hue"; the sum of white plus yellow (the "light" components of the color) as a measure of "brilliance" and the ratio of total color (*i.e.*, % red plus % yellow) to black as an indication of "saturation." These calculations are readily and quickly performed, and greatly increase the value of readings made with the N. A. colorimeter and discs.

The color analyses of the samples in groups (2), (3), and (4) were made with the new Bausch and Lomb type H. S. B. Color Analyzer. Studies with this instrument indicated that the standard Munsell discs were better suited to this type of color measurement than the N. A. discs and they were accordingly used and the results calculated into terms of hue, brilliance, and saturation. Owing to the fact that different instruments, illuminants, and color discs were employed, it is not possible to make direct comparisons between the color analysis results for group (1) and groups (2), (3), and (4), but this does not affect the placing within groups.

Cooking tests were made by steeping 25-gram samples in cold distilled water for 1 hour, draining, adding 200 cc. boiling water and boiling gently for 20 minutes, using 500 cc. tall-form lipless beakers

partly covered. At the expiration of the boiling period, the samples were drained and washed with cold distilled water. Firmness was

TABLE I

MILLING DATA, GRADE, AND WEIGHT PER BUSHEL FOR DURUM WHEAT VARIETIES

Laboratory number	Variety	Crop year	Grade	Weight per imperial bushel	Semolina yield
				Pounds	%
		GROUP 1			
14251	Mindum × Pentad	1934	1 C.W.	65.00	32.5
14252	Mindum × Pentad	"	1 C.W.	65.00	33.0
14253	Monad	"	2 C.W.	65.00	33.0
14254	Mindum	"	1 C.W.	65.00	32.2
14255	Kubanka	"	3 C.W.	64.25	32.0
14256	Arnautka	"	1 C.W.	64.25	31.2
14257	Golden Ball	"	2 C.W.	65.00	31.2
14258	Pelissier	"	1 C.W.	64.25	32.0
14259	Akrona	"	1 C.W.	64.25	31.0
14260	Nodak	"	2 C.W.	64.25	31.2
14261	Pentad	"	Red Durum	64.25	28.5
14262	Acme	"	3 C.W.	64.50	31.5
14263	Iumillo	"	Red Durum	64.75	29.5
		GROUP 2			
1270	Mindum	1935	1 C.W.	65.00	31.2
1271	Pelissier	"	2 C.W.	64.25	31.0
1272	Pelissier	"	1 C.W.	64.75	32.0
1273	Pelissier	"	1 C.W.	65.00	30.7
1274	Golden Ball	"	2 C.W.	64.75	30.7
		GROUP 3			
1277	Mindum × Pentad	1935	4 C.W.	58.75	25.7
1278	Mindum × Pentad	"	4 C.W.	61.25	26.6
1279	Mindum × Pentad	"	4 C.W.	61.00	27.0
1280	Mindum	"	3 C.W.	61.00	27.4
1281	Monad	"	5 C.W.	60.75	27.0
1282	Arnautka	"	4 C.W.	59.00	26.4
1283	Golden Ball	"	5 C.W.	57.00	24.8
1284	Pelissier	"	4 C.W.	57.75	26.0
1285	Akrona	"	4 C.W.	56.00	24.5
1286	Nodak	"	4 C.W.	60.25	29.0
1287	Iumillo × Mindum	"	3 C.W.	62.00	29.8
1288	Iumillo × Mindum	"	3 C.W.	61.00	29.6
1289	Acme	"	4 C.W.	60.00	28.6
		GROUP 4			
1404	Kubanka	1935	1 C.W.	64.25	31.8
1405	Mindum	"	1 C.W.	64.25	32.4
1406	Pelissier	"	3 C.W.	62.00	31.0

then judged by pressure between the fingers and by mastication. An attempt was made to measure the degree of disintegration by means of the turbidity of the residual water after boiling. The results obtained with several extended series of replicates, however, indicated that the variability was extremely high and these data are therefore not presented.

Experimental Results

The milling data, together with grade and weight per imperial bushel for the entire series, are presented in Table I, in which the samples are arranged in order of the groups previously described. In groups (1), (2), and (4) there are no appreciable differences in yield or weight per bushel between varieties, with the exception that the red durums Iumillo and Pentad (group 1) gave low yields, and Pelissier (group 4) was low in weight. The samples in group (3) were grown in a heavily rusted area and the yields and test weights are much lower than in the other groups. The values given probably do not represent the normal relation between the varieties.

It should be mentioned that the semolina yields obtained experimentally are always considerably lower than those obtained commercially, the object being to obtain a semolina comparable in purity to the commercial product. The normal experimental yields from plump samples vary from approximately 31 to 33%.

The protein and carotene data for both wheats and semolinas are presented in Tables II and III. The data for group (1) are presented

TABLE II

PROTEIN AND CAROTENE DATA FOR DURUM WHEAT VARIETIES (1934 CROP) [1]

Laboratory number	Variety	Wheat protein	Semolina protein	Wheat carotene (Nov. 1934)	Wheat carotene (Aug. 1935)	Semolina carotene
		%	%	*p.p.m.*	*p.p.m.*	*p.p.m.*
		GROUP 1				
14254	Mindum	16.7	14.8	2.59	2.35	1.96
14256	Arnautka	16.5	15.0	2.73	2.40	1.69
14251	Mindum × Pentad	16.8	15.3	2.96	2.37	1.99
14258	Pelissier	16.2	14.4	2.69	2.13	1.80
14259	Akrona	16.8	15.1	3.25	3.01	2.69
14252	Mindum × Pentad	18.0	16.1	3.09	2.57	2.11
14260	Nodak	17.7	15.6	2.64	2.06	1.66
14253	Monad	16.7	14.6	2.19	1.85	1.38
14257	Golden Ball	16.0	13.2	2.94	2.42	1.99
14255	Kubanka	16.9	15.2	2.30	2.05	1.56
14262	Acme	16.8	14.7	1.98	1.73	1.25
14263	Iumillo	17.6	15.2	1.96	1.84	1.54
14261	Pentad	19.5	17.4	2.02	1.71	1.33

[1] Samples are arranged in order of visual appearance of the macaroni. All results are expressed on a 13.5% moisture basis.

TABLE III

PROTEIN AND CAROTENE DATA FOR DURUM WHEAT VARIETIES (1935 CROP) [1]

Laboratory number	Variety	Wheat protein	Semolina protein	Wheat carotene	Semolina carotene
		%	%	*p.p.m.*	*p.p.m.*
		GROUP 2			
1270	Mindum	17.2	15.6	2.81	2.65
1271	Pelissier	16.9	15.2	2.25	2.21
1272	Pelissier	17.1	15.2	2.14	1.87
1273	Pelissier	16.8	14.8	3.00	3.02
1274	Golden Ball	17.4	14.4	2.35	2.25
		GROUP 3			
1277	Mindum × Pentad	15.0	13.4	4.80	4.16
1278	Mindum × Pentad	16.5	14.1	3.59	3.23
1279	Mindum × Pentad	15.0	13.3	3.22	2.61
1280	Mindum	14.3	13.2	3.72	3.72
1281	Monad	14.8	13.3	2.92	2.04
1282	Arnautka	15.3	14.1	4.50	3.34
1283	Golden Ball	16.7	14.4	3.59	2.98
1284	Pelissier	14.6	13.2	3.32	3.32
1285	Akrona	14.3	13.2	5.28	4.88
1286	Nodak	14.3	12.8	3.59	2.95
1287	Iumillo × Mindum	14.9	13.0	3.35	3.62
1288	Iumillo × Mindum	14.6	12.7	2.80	2.63
1289	Acme	13.8	12.6	2.78	2.10
		GROUP 4			
1404	Kubanka	16.0	14.5	3.12	2.36
1405	Mindum	17.0	15.0	2.83	2.40
1406	Pelissier	14.6	12.9	2.89	1.86

[1] All results are expressed on a 13.5% moisture basis.

separately because of the fact that two sets of values for wheat carotene are given the values at November 1934 being obtained upon receipt of the wheats and the August 1935 values at the time of milling. In group (1) the wheat protein varies from 19.5% in Pentad to 16.0% in Golden Ball; for group (2), from 17.4% in Golden Ball to 16.8% in Pelissier; in group (3), from 16.7% in Golden Ball to 13.8% in Acme, and in group (4), from 17.0% in Mindum to 14.6% in Pelissier. The protein content of the semolinas follows a similar general trend. In the storage interval of nine months the carotene content of the wheats in group (1) decreased by an average of 0.36 p.p.m. Carotene is at a maximum for this group in Akrona with 3.01 p.p.m. in the wheat and 2.69 p.p.m. in the semolina. The minimum for wheat occurs in Iumillo, 1.96 p.p.m., and for semolina in Acme, 1.25 p.p.m. In groups (2) and (4) the carotene contents vary only slightly, but in group (3) quite wide variations are found with a maximum for wheat of

5.28 p.p.m. in Akrona and 4.88 p.p.m. in the semolina. The minimum for wheat occurs in Acme with 2.78 p.p.m., and for semolina in Monad with 2.04 p.p.m. The extremely high pigment content of certain of the samples in this group is associated with a low grade figure which is influenced by the content of thin rusted and immature kernels. Kernels of this type possess an abnormally high pigment content ranging from 7 p.p.m. to 9 p.p.m. of carotene.

It is worthy of note that a very irregular relation exists between wheat carotene and semolina carotene; this may indicate variations in pigment distribution within the various portions of the wheat kernel in different varieties but our present knowledge of the nature and properties of these pigments is not sufficiently extensive to permit definite conclusions to be drawn.

The color analysis data for group (1) are presented in Table IV and graphically in Figure 1, and for groups (2), (3), and (4) in Table V and graphically in Figure 2. The terms employed in connection with

TABLE IV

COLOR ANALYSIS DATA FOR MACARONI. DURUM WHEAT VARIETIES (1934 CROP) [1]

Laboratory number	Variety	White	Yellow	Red	Black	"Hue" (Ratio yellow to red)	"Brilliance" (White + yellow)	"Saturation" (Ratio yellow + red to black)
		%	%	%	%			
				GROUP 1				
14254	Mindum	19.0	32.1	14.0	34.9	2.30 : 1	41.1	1.32 : 1
14256	Arnautka	22.1	29.7	12.5	35.7	2.38	51.8	1.18
14251	Mindum × Pentad	20.0	27.0	15.3	37.8	1.83	47.0	1.09
14258	Pelissier	18.3	28.0	18.2	35.5	1.54	46.3	1.30
14259	Akrona	17.0	27.9	20.5	34.8	1.36	44.9	1.39
14252	Mindum × Pentad	18.0	24.5	17.3	40.2	1.42	42.5	1.04
14260	Nodak	16.4	24.6	20.3	39.7	1.21	41.0	1.14
14253	Monad	21.6	23.2	18.0	37.1	1.29	44.8	1.11
14257	Golden Ball	24.0	25.0	14.5	36.5	1.72	49.0	1.08
14255	Kubanka	22.9	25.5	15.4	36.2	1.68	48.4	1.13
14262	Acme	20.2	23.0	20.7	36.2	1.11	43.2	1.21
14263	Iumillo	18.1	23.1	18.2	40.6	1.27	41.2	1.02
14261	Pentad	14.2	20.0	18.3	47.5	1.09	34.2	0.80

[1] Samples are arranged in order of visual appearance of the macaroni.

the data for group (1) have already been described, but the values given in Table V require some explanation. The computed values for "hue," "brilliance," and "saturation" are calculated by means of the formulae outlined by Nickerson (1929). The values in the column headed "Ratio B : S" are obtained by dividing the values for "brilliance" by the values for "saturation," and the values in the column

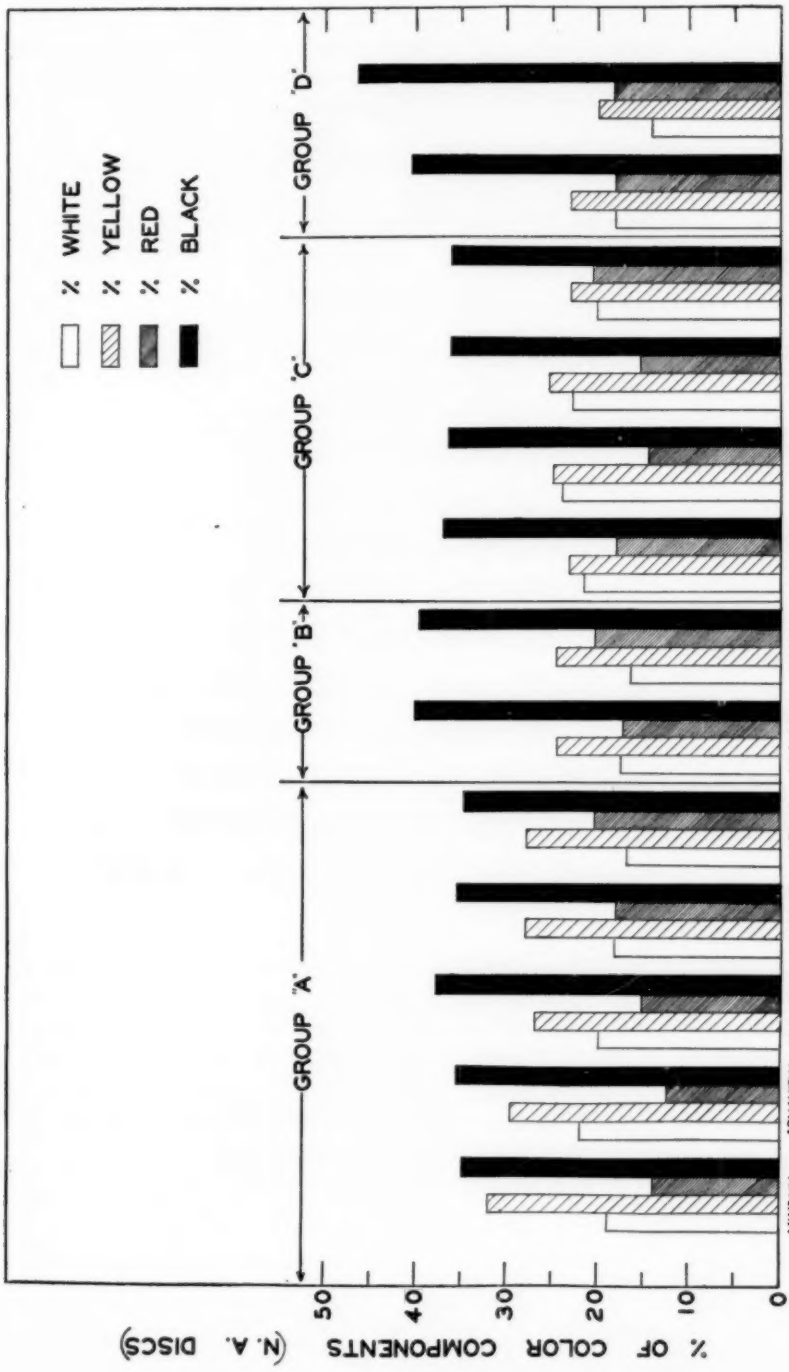

Figure 1. Histograms showing the color analyses of macaroni made from the durum wheat varieties comprising Group 1 (1934 Crop). The varieties are arranged in order of decreasing visual color score.

TABLE V

COLOR ANALYSIS DATA FOR MACARONI. DURUM WHEAT VARIETIES (1935 CROP) [1]

Laboratory number	Variety	Hue	Brilliance	Saturation	Ratio B : S	Color score
		GROUP 2				
1273	Pelissier	22.13	6.47	5.38	1.20 : 1	18.4
1270	Mindum	22.91	7.14	5.57	1.28	17.9
1272	Pelissier	21.51	6.51	5.05	1.29	16.7
1271	Pelissier	22.25	6.53	4.80	1.36	16.4
1274	Golden Ball	21.55	6.76	4.83	1.40	15.4
		GROUP 3				
1280	Mindum	22.74	7.06	6.30	1.12 : 1	24.4
1282	Arnautka	22.77	6.65	5.68	1.17	23.7
1278	Mindum × Pentad	22.30	6.82	5.64	1.21	19.9
1277	Mindum × Pentad	22.22	6.80	5.45	1.25	19.8
1287	Iumillo × Mindum	22.30	6.93	5.97	1.16	19.2
1279	Mindum × Pentad	21.65	6.70	5.59	1.20	18.0
1285	Akrona	22.58	6.32	4.97	1.27	17.8
1281	Monad	21.53	6.81	5.61	1.21	17.8
1288	Iumillo × Mindum	21.60	7.10	5.78	1.23	17.6
1284	Pelissier	22.25	6.90	5.45	1.27	17.5
1286	Nodak	22.20	6.76	5.12	1.32	16.8
1289	Acme	21.62	6.99	5.19	1.35	16.0
1283	Golden Ball	21.85	6.71	4.84	1.39	15.7
		GROUP 4				
1404	Mindum	22.57	6.58	5.90	1.12 : 1	20.2
1405	Pelissier	22.05	6.35	5.02	1.27	17.4
1406	Kubanka	22.49	6.60	4.96	1.33	16.9

[1] Within each group, the samples are arranged in order of visual appearance of macaroni.

headed "color score" are obtained by dividing the "hue" figure by the above ratio value. This method, which will be described in detail elsewhere, gives a single figure estimate of color which places the samples in identically the same order as a careful visual classification.

Considering first the samples in group (1), the results show that a very wide range in color exists. Classification of these samples was originally based on visual examination and was made before the results of the color analyses were available. It was not found feasible to grade the samples in a single series and they were accordingly classified into groups as follows:

(*a*) Color—normal, clear-bright yellow to slightly brownish in the lower members:
Mindum
Arnautka
Mindum × Pentad (No. 14251)
Pelissier
Akrona

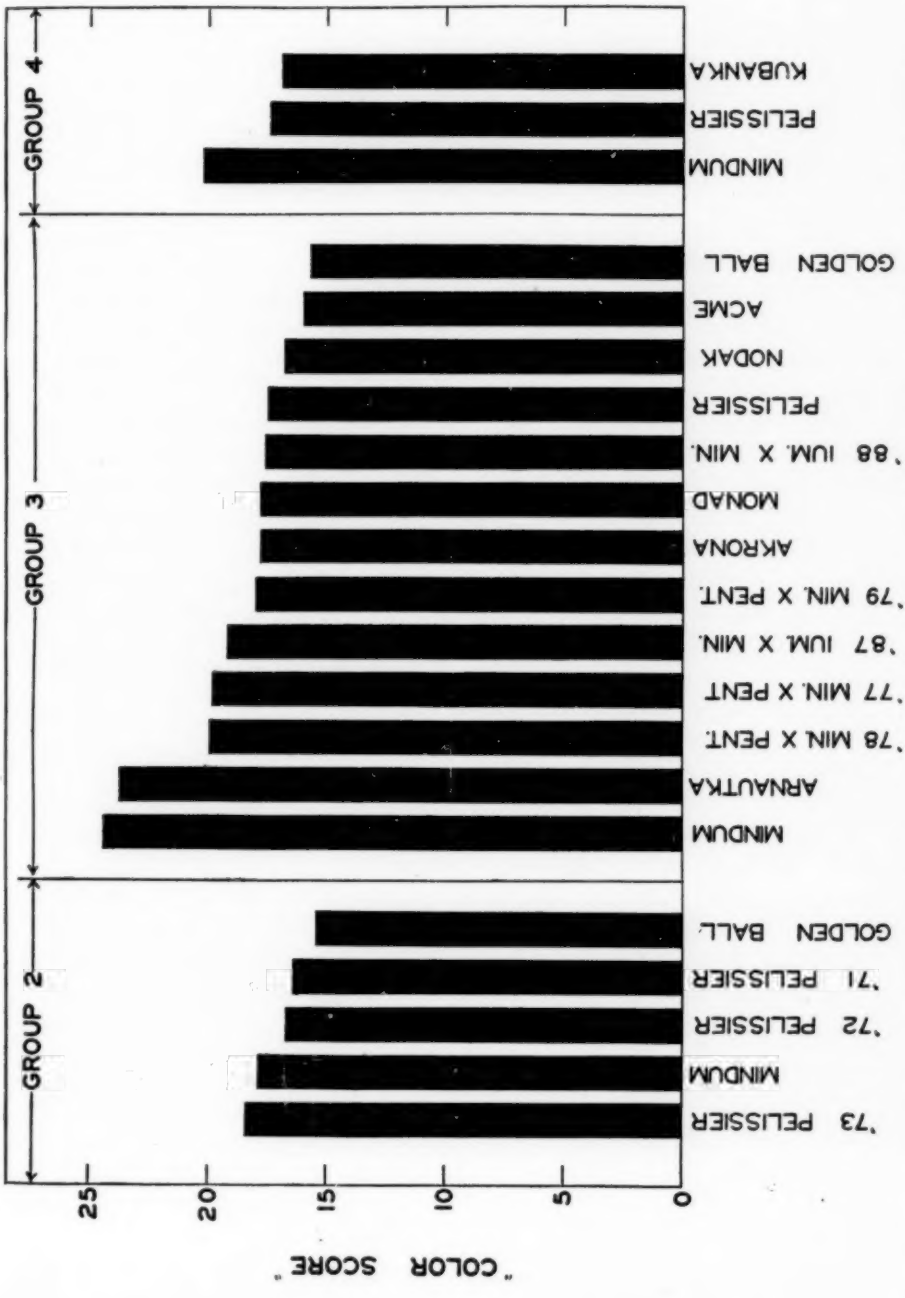

Figure 2. Histograms showing the computed color scores of macaroni made from the durum wheat varieties comprising Groups 2, 3 and 4 (1935 Crop).

(*b*) Color—darker and distinctly brown (*i.e.*, red):
Mindum × Pentad (No. 14252)
Nodak
(*c*) Color—pale, yellowish to distinctly red:
Monad
Golden Ball
Kubanka
Acme (visibly pink)
(*d*) Color—dark, definitely brown and decidedly gray:
Iumillo
Pentad

After the color data were secured, an attempt was made to classify the samples on this basis only and without reference to visual score. The results placed the first five and last two samples in exactly the same order with only minor misplacings within the (*b*) and (*c*) groups, this being due to the fact that visually no attempt was made to classify these samples within their respective groups.

From a color standpoint only the samples in class (*a*) can be considered as being commercially valuable, the remainder being unsatisfactory except possibly for breeding purposes. An exception to this statement is to be found in Kubanka, which is usually classed along with Mindum as representing the two most satisfactory varieties. The sample used in these tests was a pure line selection grading 3 C. W. and was not representative of the variety. These facts probably account for the low placing of this sample. A comparison of the carotene content of the wheats with the color classification of the macaroni samples indicates a low degree of association between these two factors, and it would appear that durum wheat carotene is only valuable for eliminating undesirably low pigment strains.

Classification of the samples in groups (2), (3), and (4) is greatly facilitated by the use of the "color score" values previously referred to. With macaroni, these values agree perfectly with the visual placing. Sufficient data have not yet been accumulated to assign definite limits for desirable and undesirable samples in terms of "color score" values, but from the material so far examined a minimum of 18 units would appear to be about the lower level of desirable color. On this basis, these groups classify as follows:

Group (2)

Satisfactory color —Pelissier No. 1273
Mindum No. 1270
Unsatisfactory color—Pelissier No. 1272
Pelissier No. 1271
Golden Ball No. 1274

Group (3)

Satisfactory color —Mindum No. 1280
Arnautka No. 1282
Mindum × Pentad No. 1278
Mindum × Pentad No. 1277
Iumillo × Mindum No. 1287
Mindum × Pentad No. 1279

Intermediate color —Akrona No. 1285
Monad No. 1281
Iumillo × Mindum No. 1288
Pelissier No. 1284
Unsatisfactory color—Nodak No. 1286
Acme No. 1289
Golden Ball No. 1283

Group (4)

Satisfactory color —Mindum No. 1405
Intermediate —Pelissier No. 1406
Unsatisfactory —Kubanka No. 1404

As in the case of group (1), little, if any, relation appears to exist between wheat carotene and macaroni color. An interesting point to be noted is the fact that Kubanka again takes a low placing. No information is available regarding the parent of this sample and therefore no conclusions can be attempted regarding the abnormal behaviour of this variety.

The results of the cooking tests on all groups were very similar. All the samples cooked well and no appreciable difference could be detected in either the tenderness of the cooked material or in the amount of disintegration which was very small in all cases and compared favorably with that of a high grade commercial macaroni.

Summary

Thirty-four samples of experimentally grown durum wheats produced in Western Canada during the years 1934 and 1935 have been milled into semolina and macaroni produced therefrom.

Official grades, weight per bushel, and milling yields are presented, together with protein and carotene data for both wheats and semolinas.

Color analyses have been made upon the macaroni and a single figure estimate, derived from the values for "hue," "brilliance," and "saturation," has been developed which corresponds with visual color score.

Of the samples examined, only Mindum, Arnautka, several new Mindum-Pentad crosses, Pelissier, Akrona, and a Iumillo × Mindum cross produced macaroni of satisfactory commercial value from the standpoint of color and appearance.

No substantial difference was found in the cooking behaviour of the samples tested.

Evidence has been obtained that little, if any, relation exists between carotenoid content of durum wheat and the color of macaroni produced therefrom.

Acknowledgments

The authors are indebted to L. D. Sibbitt, who conducted the macaroni making and carotene tests, to H. Johannson for the color analyses of macaroni, and to I. S. Snider, who performed the milling tests.

Literature Cited

Baker, J. C., Parker, H. K., and Freese, F. B.
1933 The measurement of color in flour and bread by means of Maxwell discs. Cereal Chem. **10**: 437–446.
Binnington, D. S., and Geddes, W. F.
1936 Experimental durum milling and macaroni making technique. Cereal Chem. **13**: 497–521.
Dictionary of Spring Wheat Varieties
1933 Northwest Crop Improvement Association, Minneapolis, Minn.
Nickerson, Dorothy
1929 A method for determining the color of agricultural products. U. S. D. A. Tech. Bull. 154.
Phillips, C. L., and Shollenberger, J. H.
1927 Durum wheat and durum wheat products. A selected list of reference. U. S. D. A. Bureau of Ag. Ec.: USGSA-G1-42.

THE INFLUENCE OF INDIVIDUAL MILLING TECHNIQUE ON FLOUR AND LOAF CHARACTERISTICS[1]

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(Read at the Annual Meeting, June, 1936)

The drive to secure comparable results from the work of different laboratories in tests of baking quality of the same flours has in the last decade led to the voluntary expenditure of much time and effort by committees of the American Association of Cereal Chemists. One reward has been fairly general acceptance of a system of standardization of procedures as a working basis for test baking and loaf judging. Another outcome not as yet thoroughly evaluated, appears to be a growing recognition of the existence of a troublesome residual variation in the results of baking in spite of the standardization achieved. Many sources of this variation have been recognized and careful research has been undertaken to examine the possibilities of better control.

It is undoubtedly apparent to all that one potential source of variation in loaf characteristics lies in the art which reduces wheat to a condition suitable for manufacture of bread. The claim that it is premature to consider this problem until more progress has been made in the control of the baking procedure itself must be acknowledged as having considerable weight, and yet it is not by any means without value to examine the need for such research at this point, quite independently of any hope of achieving reform. Perhaps reform is really not needed, but who is in a position to say so until some exploration has been made? It therefore appealed to one of us, as chairman of the Committee on Methods for the Northwest Section of the Association, that a preliminary examination of this problem might yield valuable results. Promise of cooperation in execution of a project being secured from several laboratories, it was decided to institute the research so that data might be secured for examination of its value. The following report embodies the results of the investigation, which in its final stages assumed the nature of a joint study between the National and the Northwest Sectional Committees on Methods of Analysis.

Organization of Research

In order to have milling technique as the sole variable in this study, all work other than the actual milling was performed in the one labora-

[1] Paper No. 1432, Scientific Journal Series, Minnesota Agricultural Experiment Station.

tory. During runs of three different wheat blends, large samples of wheat were drawn off from the stream going to the scouring machinery in a 500-barrel commercial mill. Each sample was thus thoroughly mixed and reasonably clean. To each of 12 collaborators, one aliquot of each of the three wheats was sent for reduction according to his own method of experimental milling, with instruction for return to the senior author of 800–1000 grams of the flour secured. No attempt was made to have milling yields recorded, since the milling equipments to be used and procedures to be followed were very diverse. Indeed some of the laboratories customarily ignored such details as yields from experimental runs.

The following laboratories collaborated in grinding the three wheats on their experimental mills for this project, and to their personnel our sense of appreciation is considerable. Hereafter, reference to these cooperating laboratories will be made by letter code, both for convenience and to eliminate selective judgments.

Commander-Larabee Corp., Minneapolis
International Milling Co., Minneapolis
King Midas Mill Co., Minneapolis
Minnesota Agr. Exp't Station, St. Paul
Minnesota State Testing Mill, Minneapolis
Montana Agr. Exp't Station, Bozeman
North Dakota Agr. Exp't Station, Fargo
Northwestern Consolidated Milling Division, Minneapolis
Pillsbury Flour Mills Co., Minneapolis
Russell Miller Milling Co., Minneapolis
U. S. D. A., Grain Division, B. A. E., Washington, D. C.
Washburn Crosby Co. Inc., Minneapolis

In addition, the commercial mill providing the wheat samples also supplied samples of the "commercial patent" and "commercial straight" flours derived from each wheat. These flours will be referred to as C. P. and C. S.

Uniform cold storage accommodations for the finished flours were provided by the senior author at the baking laboratory. Metal cans with tight fitting lids were used. Soon after storage of each flour a moisture determination was made by the vacuum-oven method with a single overnight drying. At a later time, duplicate determinations of ash, protein, and diastatic activity were made by the same analyst, the results being corrected to a 13.5% moisture basis in accordance with the earlier moisture finding.

All baking tests were completed by the senior author in a period of a little over one month. For the majority of the flours several baking tests were made, these varying in the amount of sugar used (zero, 2.5%, 5%, and 7.5%), and in the time of mixing (both 2 min. and 5 min.) for the 5% sugar formula. The latter tests were run in duplicate for all flours, with randomization of order, first and second tests being separated by one or more days.

The following statistical analysis of the baking data is confined to the latter duplicated tests, and to the volume, grain, and absorption measurements. Loaf volume was determined in the Werner apparatus, using rape seed, calibration having been secured in terms of cast aluminum model "loaves" of known volume. The scores for grain were secured by direct comparison of the cut loaves with preserved standards. Absorption of the flour in preparing the doughs, expressed in terms of a 13.5% moisture flour, is open to errors of personal judgment, since it was determined from tactile sensation. Control of this was attempted by having all previous absorption figures for each flour before the operator as each dough was prepared. This may have instituted *too much* control, as will be indicated later on.

The Data

The following tables present that portion of the basic data accumulated from the chemical analyses and baking tests which seem of more general interest. In all, over 200 loaves were baked and scored for eight characters. Where triplicate runs were made, only the first pair of tests are included for those cases. The headings of the tables will be relied upon to define the data, and that on color of the crumb will not be discussed further in this article.

Statistical Analyses

Chemical Differentiation of the Flours

The chemical analysis data summarized in Table I, where the single moisture test and averages of the duplicate tests for ash, protein, and diastatic activity are given, show in superficial inspection some decided differences between the flours returned by the milling laboratories. There are considerable differences in all tests for any one sample, and these differences appear to be somewhat consistent between laboratories for the three wheat samples. In this connection it is particularly interesting to note the high diastatic activity values for the flours from laboratory E, which had a decided effect on the baking data when no sugar was used in the mix (see Tables II, III, and IV).

The tendency for laboratories to mill to different moisture levels is shown by an average correlation between the results for each pairing of the flours of $r = +.86$. This same procedure might also be applied to the other chemical tests, but since they were made in duplicate it is of added interest to consider the differentiation in terms of the error of each chemical test. This may be done conveniently by using the "analysis of variance" technique. The results of application of this test are so clear cut that there seems little point to giving a table of details in terms of the actual variances found. Not only are the three samples clearly differentiated with respect to all three chemical analy-

ses, but also the flours from the 12 laboratories are clearly differentiated, chemically, for any one wheat sample, and these differences change significantly from one sample to another (*i.e.*, there is a significant "interaction"). Thus, in terms of chemical analyses for protein, ash, and diastatic activity, the flours differ significantly in composition when the same wheat sample is milled by several laboratories, and these differences are not solely a function of the milling technique but also of the wheat sample used.

TABLE I
CHEMICAL TESTS [1]

Laboratory	Sample 1				Sample 2				Sample 3			
	Moisture	Ash	Crude protein	Diastatic activity [2]	Moisture	Ash	Crude protein	Diastatic activity [2]	Moisture	Ash	Crude protein	Diastatic activity [2]
	%	%	%		%	%	%		%	%	%	
A	13.78	0.43	11.04	160	13.10	0.51	14.65	179	14.44	0.46	12.54	162
B	13.05	.44	10.75	175	12.47	.49	14.65	166	13.38	.50	12.45	186
C	12.99	.48	10.85	145	12.68	.52	14.45	130	12.70	.52	12.52	141
D	12.41	.38	10.78	143	12.30	.48	14.59	124	12.25	.48	12.51	146
E	13.47	.40	10.55	450 [3]	13.42	.45	13.94	282 [3]	13.99	.45	12.28	265 [3]
F	11.62	.48	11.14	172	11.93	.56	15.16	148	11.63	.55	12.65	155
G	13.65	.38	10.68	155	13.30	.45	14.62	125	13.52	.44	12.40	126
H	13.43	.41	10.92	166	13.52	.51	14.62	167	13.63	.46	12.73	173
I	13.84	.40	10.73	155	13.20	.46	14.48	129	14.08	.46	12.77	129
J	13.14	.37	10.61	117	13.17	.42	13.80	108	13.62	.41	11.82	120
K	13.32	.38	10.92	114	13.37	.43	14.29	114	13.65	.42	12.53	140
L	13.76	.37	11.16	147	14.06	.46	14.71	117	13.57	.46	12.91	90
Average	13.21	.41	10.84	150	13.13	.47	14.50	137	13.37	.46	12.51	143
C.P.	13.79	.37	10.46	226	—	—	—	—	13.21	.42	12.46	222
C.S.	13.57	.44	10.97	254	13.10	.50	15.25	240	13.17	.50	13.01	245

[1] Ash, crude protein, and diastatic activity corrected to 13.5% moisture basis.
[2] Milligrams of maltose from 10 g. of flour after 1 hour's diastasis at 30° C.
[3] Omitted from average.

It is of interest to record quantitatively the error of analysis characterizing each type of chemical determination. Table V gives the standard deviation of the error, and also the range of error about the true mean to be expected in 99 trials out of 100 assuming a "normal" curve of distribution. The protein value is in accord with that usually found, while the ash error is roughly 50% greater than that found by Treloar in a Sub-committee Report of 1932. The error of the diastatic activity determination as yet hardly warrants comparative notes.

TABLE II

LOAF VOLUME DATA, *Cubic centimeters*

	Treatment							
	Zero sugar, 2 min. mix		5% sugar, 2 min. mix			5% sugar, 5 min. mix		
			Flour					
Laboratory	1	2	1	2	3	1	2	3
A	350	—	565	670	635	545	670	615
			590	670	600	535	595	600
B	360	390	570	670	625	535	655	595
			610	690	600	580	705	580
C	325	355	580	685	610	550	640	605
			585	640	610	525	645	550
D	320	375	580	690	625	510	655	595
			610	645	610	525	650	570
E	610 [1]	460 [1]	570	665	610	570	700	605
			635	660	585	610	675	580
F	360	360	565	715	575	530	665	600
			580	655	600	510	625	580
G	365	360	555	645	585	565	665	595
			595	635	590	550	650	590
H	345	385	565	635	610	545	654	590
			610	595	580	520	615	565
I	320	355	590	615	605	545	650	620
			605	620	600	615	615	585
J	345	360	570	650	600	540	620	600
			615	640	565	630	630	595
K	360	360	550	660	650	540	660	600
			615	640	610	530	670	570
L	340	355	545	640	645	535	655	590
			600	615	605	555	645	550
Average	345	366	586	652	605	550	650	589
C.P.	360	—	535	—	615	515	—	590
			590	—	580	520	—	575
C.S.	360	—	570	690	—	530	660	—
			580	700	—	660	645	—

[1] Omitted from average.

TABLE III
COLOR OF CRUMB, *Score*

	Treatment							
	Zero sugar, 2 min. mix		5% sugar, 2 min. mix			5% sugar, 5 min. mix		
	Flour							
Laboratory	1	2	1	2	3	1	2	3
A	95cw	—	97c	97gc	98c	97c	93gc	98c
			96gc	97c	99cw	95gc	97g	96c
B	96cw	98cw	96gc	95gc	95cg	96y	98gc	99w
			96gc	97c	98c	98cw	99cw	95gw
C	95cw	97c	98cw	97c	99cw	98c	99cw	96c
			99c	96cg	99cw	98cw	97cg	96gw
D	95cw	96cg	97c	98c	94cg	95gy	98c	98w
			98c	95gc	95cg	97c	97cg	95gw
E	—	99c	94gc	99cw	94cy	94gc	99cw	98w
			94gw	100cw	97cg	100w	100w	97w
F	94c	95cg	94gc	93gy	91gw	93gy	96cg	100w
			92gc	91gy	92y	92gy	95cg	94gw
G	97cw	97c	99w	99cw	97c	97c	100cw	94cg
			99c	94gy	98c	99cw	98c	98cw
H	94cgw	97c	94gw	100cw	95cg	94gc	95cg	96c
			95gc	99c	97cg	93gc	95cg	97w
I	93y	97c	96gc	96cg	95cg	100cw	97cg	100w
			95gc	86cg	98c	95cg	95cg	99w
J	96cw	98c	97c	98c	98c	100cw	100cw	99w
			98c	99c	98c	98c	98c	99cw
K	93y	97c	97c	99cw	99cw	100cw	98c	95cg
			98c	98c	99cw	99cw	99cw	94gw
L	95cw	94cg	98cw	97c	97c	96c	98c	95cg
			93gw	93gc	94g	96gc	96cg	97w
C.P.	96cw	—	100w	—	100cw	100cw	—	100cw
			100w	—	100cw	98cw	—	100cw
C.S.	97cw		99w	98c	—	95gy	94g	—
			99c	98w	—	94g	98cg	—

TABLE IV

GRAIN OF CRUMB, *Score*

	Treatment							
	Zero sugar, 2 min. mix [1]		5% sugar, 2 min. mix			5% sugar, 5 min. mix		
			Flour					
Laboratory	1	2	1	2	3	1	2	3
A	90	—	97	96	97	98	96	96
			97	95	96	96	97	95
B	90	90	95	95	95	97	96	96
			97	94	95	96	96	98
C	90	90	96	96	96	97	97	96
			97	95	97	97	97	98
D	90	90	97	97	96	96	97	96
			97	96	96	96	97	98
E	95 [2]	96 [2]	96	97	94	96	97	95
			97	95	96	96	96	98
F	90	90	96	94	95	96	96	97
			96	93	96	96	96	97
G	90	90	96	96	97	98	97	95
			97	96	96	96	97	98
H	90	90	95	95	96	97	94	95
			97	97	97	96	96	97
I	90	90	97	95	96	97	98	96
			96	96	96	97	97	98
J	90	90	96	97	96	98	95	94
			97	96	97	96	96	98
K	90	90	96	96	96	98	95	95
			97	95	97	97	97	97
L	90	90	97	96	96	97	97	96
			97	95	97	96	97	97
Average	90	90	97	96	96	97	96	97
C.P.	90	—	96	—	96	96	—	97
			97	—	97	96	—	95
C.S.	90	—	96	95	—	96	97	—
			97	97	—	97	96	—

[1] All grain scores were "tight" when no sugar was used.
[2] Omitted from average.

TABLE V
ERROR DISPERSAL VALUES FOR THE 3 CHEMICAL TESTS

	Number of duplicates	Standard deviation	Range [1]
Protein	36	.0549	± .141
Ash	36	.0069	± .018
Diastatic activity	36	2.28	±5.9

[1] Defined in text.

Baking Tests

As has been indicated previously, the statistical analysis of the baking data are confined to the 5% sugar formula for 2 and 5 min. mixing times, where duplicate tests permit of the evaluation of the experimental error. Loaf volume, grain of crumb, and absorption of flour will alone be considered in this connection, because of the greater objectivity possible in their measurements.

Some appreciation of the variability in loaf volume, grain, and absorption between duplicate tests, all other conditions being unaltered, may be secured from inspection of the basic data in Tables II, IV, and VI. We shall proceed directly to the "analysis of variance" for these data in order to measure that error quantitatively for each variable, and in terms of it to test for the existence of significant differentiation between the laboratories after allowing for the influence of the different wheats and mixing times. Table VII presents a summary of the variances resulting from this partition.

Our chief concern herein is with the question of whether the effect of the rather highly diverse experimental milling techniques of the various laboratories, yielding chemically different flours, may be considered to have exercised a significant effect upon the water absorption of the flour, the volume of the loaf of bread, or the grain score for the crumb. Since three different wheat samples and two methods of dough preparation entered the experiment, account may be taken of these factors, together with their interactions, in a complete analysis of the data. While it is of no consequence to the main objective if the three wheats are differentiated or the two methods affect the results differently, it is of interest to learn whether there is a significant "interaction" of laboratories with samples and/or methods. The complete partition of dispersal is therefore given in Table VII.

The error existing in any one type of determination, such as loaf volume, may be measured directly in terms of the differences between duplicates. This error, expressed as a variance, is the "residual" value given in Table VII. This same error may also be measured from the means of sets of determinations provided that those sets are comparable to random samples from the whole. Now the sets provided by labora-

tories, samples, methods, or their interactions, are not truly random sets in origin, but they may be fully comparable to random sets if there is no real differentiation between laboratories, between samples, between effect of methods, or between interactions. If such differentiation does in truth exist, then the variance due to them must be

TABLE VI

ABSORPTION OF FLOUR, *Per cent*

	Treatment							
	Zero sugar, 2 min. mix		5% sugar, 2 min. mix			5% sugar, 5 min. mix		
			Flour					
Laboratory	1	2	1	2	3	1	2	3
A	63	—	64	64	65	61	63	62
			62	64	64	61	63	62
B	64	63	64	63	63	63	60	62
			62	63	63	61	62	62
C	64	63	64	64	62	62	60	61
			63	64	62	61	62	61
D	62	63	63	63	62	60	60	61
			61	63	62	60	62	61
E	63	64	61	62	63	61	61	62
			62	62	62	60	62	61
F	62	63	63	63	62	60	60	61
			61	63	62	60	62	61
G	64	64	64	63	63	61	61	62
			62	64	63	61	63	62
H	63	64	65	64	63	61	61	62
			62	64	63	61	63	62
I	63	64	64	64	63	61	61	62
			62	64	63	63	63	62
J	63	64	64	64	63	61	61	62
			62	64	63	63	63	62
K	63	64	65	64	63	61	61	62
			62	64	63	61	63	62
L	63	64	63	64	63	62	61	62
			62	64	63	61	63	62
Average	63	64	63	64	63	61	62	62
C.P.	63	—	65	—	64	62	—	61
			62	—	64	62	—	63
C.S.	64	—	65	66	—	61	64	—
			63	63	—	64	63	—

expected to *exceed* the residual. Wholly acceptable demonstration of such differentiation from any set of data in hand may only be considered given when the increase has a remote possibility of itself being a mere sampling effect. Fisher's z test aims to provide a measure of this acceptability in terms of the probability of the difference being due to chance. In Table VII it may be noted that in most cases the variance determined from such sets exceeds the residual. In only those cases asterisked is the increase to be considered large enough to warrant a conclusion of real differentiation. One asterisk indicates a probability of the increase being due to chance of between 5% and 1%, while two asterisks indicate that the probability is less than 1%.

TABLE VII

ERROR VARIANCES AS ESTIMATED FROM THE SEVERAL POSSIBLE SOURCES

Source	Degrees of freedom	Variances		
		Loaf volume	Crumb grain	Flour absorption
Between laboratories (l)	11	873	1.219	2.916 [1]
Between samples (s)	2	85,563 [1]	4.406 [2]	5.340 [1]
Between methods (m)	1	11,917 [1]	8.507 [1]	85.563 [1]
Interactions (l × s)	22	840	0.425	0.492
Interactions (l × m)	11	661	1.028	.320
Interactions (s × m)	2	3,475 [1]	1.525	1.646
Interactions (l × s × m)	22	398	.700	.313
Residual (Experimental error)	72	571	.910	.757

[1] Ratio of variance to that of residual exceeds the 1% point for random sampling.
[2] Ratio of variance to that of residual exceeds the 5% point for random sampling.

It is extremely interesting to note that there is clearly no ground in these data for concluding with confidence that the various milling techniques and types of equipment employed have had any significant effect upon loaf volume or grain score of crumb, the two most important objectively made measurements in which interest centers. Demonstration of differentiation involving the laboratory millings is confined to water absorption of the flours produced, which is an unexpected and perhaps unreasonable result. It is, indeed, seriously open to question for its validity, because the method of determining absorption was highly conducive to identical duplicates, *i.e.*, to a fictitiously low estimate of the real error of the absorption determination. It is, on the other hand, not at all surprising to note that the three wheats used gave significantly different results, as also did the two mixing times.

Summary

Three wheat samples, milled experimentally in 12 laboratories according to their respective customary procedures, yielded the flours for this study.

Chemical differences in the protein, ash, and diastatic activity of the flours submitted are not confined solely to the three wheats milled. They are extended to a differentiation of the flours returned from the laboratories for any one wheat, and this differentiation changes significantly from one wheat sample to another.

The baking tests made for two mixing times, while differentiating the wheats with respect to the three variables, loaf volume, grain of crumb, and absorption of the flour, fail to differentiate the flours submitted by the laboratories for any one wheat sample or time of mixing, as far as loaf volume and grain of crumb are concerned. A significant differentiation of laboratory millings noted in the flour absorption figures is probably spurious and due to excessive control of this determination.

While the variation in the results of replicated bakings remains as large as it is at present, there seems to be no call for serious effort toward securing a more uniform experimental milling technique in as far as preparation of samples for baking procedures in which diastatic activity is not a factor. There is need for further work upon the experimental milling technic in order to improve the forecasting of the ash, protein, and diastatic activities of commercially milled flours.

Acknowledgments

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BARLEY AND MALT STUDIES. II. EXPERIMENTAL MALTING OF BARLEYS GROWN IN 1935 [1]

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(Read at the Annual Meeting, June, 1936)

Introduction

The regional investigations on the malting quality of barleys have been continued on essentially the same basis as reported before this Association in 1935.][2] The studies on experimental malting methods not reported here and the differences in composition between the experimental and commercial malts in 1934 have led to certain modifications in the malting procedure used in 1935. The changes concerned, consist principally in malting at a somewhat lower moisture content and in drying the malt in the individual compartments used for growing the barleys in the malt chamber instead of in loosely woven burlap bags. Likewise, care has been taken in drying the malts, so as to stop the drying procedure before the moisture content has been reduced to less than about 4.5%. The drying was done in a shorter time, with temperatures somewhat different than those of last season. These changes in malting procedure have helped in eliminating some of the difficulties experienced in the malting studies of 1934.

Comparison of Commercial and Experimental Malting

Samples of commercial barleys of different types and from different regions were secured through cooperation with various malting companies. Likewise these companies supplied representative malts made from these barley lots in their plants. The barley samples obtained were malted under uniform procedure in the experimental unit and a detailed comparative study was made of the malts obtained from the commercial plants and those produced in the experimental unit. The results presented in summary form in Figure 1 show a surprisingly close agreement between the fifteen lots of malt studied

[1] Based on cooperative investigations between the Division of Cereal Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture and the Wisconsin Agricultural Experiment Station. The cooperative investigations include the agricultural experiment stations of California, Colorado, Illinois, Iowa, Michigan, Minnesota, Montana, Nebraska, North Dakota, Ohio, and South Dakota where the uniform barley varietal series are grown each year. The Federal W. P. A. has contributed to the research program during the past year through a grant under the University of Wisconsin W. P. A. Project 425. The United States Maltsters Association has cooperated through an industrial fellowship grant to the University of Wisconsin.

[2] Barley and malt studies: I. Developing new varieties of barley for malting and their properties, Cereal Chem. 12: 596–609 (1935).

in this comparative series. Kernel weight when reduced to dry basis was about the same for both commercial and experimental malts.

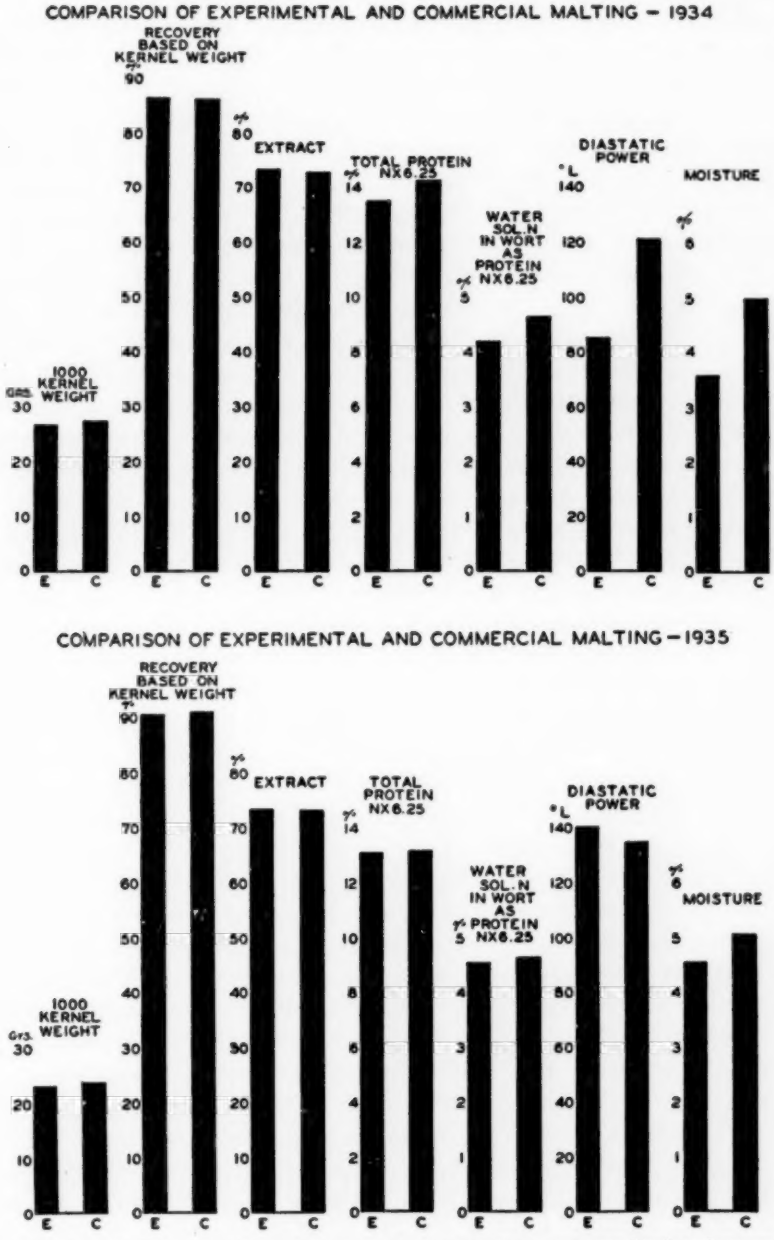

Figure 1. Graphic comparison of the malts produced in the experimental unit and commercial malts from the same barleys. Average of data from the barleys malted in 1934 and 1935. (*E*) Malts produced in experimental unit, (*C*) malts from commercial plants.

The experimental malting in 1935 where moisture content was controlled rather closely both in steeping and growing of the barley has resulted in about the same percentage recovery of malt based on kernel weight as in the commercial malting. The malts produced in the experimental unit averaged 0.7% higher in extract than the commercial malts from the same barleys. These figures indirectly indicated a somewhat lower respiration loss, and there was a better modification of the endosperm mass in the experimental malting procedure. The total protein in the malt as well as the soluble nitrogen content of the worts expressed as protein for convenience of comparison, were 0.2% and 0.3% higher respectively in the commercial malts. This higher value for soluble nitrogen in the wort in the commercial malts was accounted for in the malts produced in one plant, which were unusually high in this constituent. The average diastatic power of the malts produced in the experimental unit was 3.4° L. higher than that for the malts produced in the commercial plants. In general, the moisture content of the dried malts produced at the commercial plants was slightly higher than the malts produced in the experimental unit; an average of 5.1% in contrast to 4.6% in the experimental malts. Moisture content is associated directly with drying conditions, and in all probability has a significant relationship with the diastatic power obtained in malts. On the whole, however, the moistures were in sufficiently close agreement so that a more or less direct comparison of diastatic power in the various malts can be made. In view of the relationship of drying and moisture content to diastatic power, the difference might have been further emphasized had the drying of the malts from the experimental unit been stopped at the same moisture content as that of the commercial malts.

The comparison of the results obtained in 1935 with those reported in 1934 in a similar series shows that in general the experimental malting has been brought more nearly in line with commercial malting by the various changes in malting procedure mentioned earlier. The average moisture content of the 1934 experimental malts was 3.6% in contrast with 5.0% moisture for the commercial malts. This is rather a large difference and probably important in relation to the comparative composition of the two lots of malts. Experiments concerning the relation of moisture and temperatures during drying have been conducted, which point to the possibility that the lower diastatic power in the experimental malts produced in 1934 may be accounted for in the most part by the low moisture content associated with drying. In all probability other changes such as moisture content used in steeping and malting also have helped in bringing the results obtained in experimental malting in very close agreement with the average results obtained in the commercial malting plants.

Comparison of Master Brewer's Show Samples from Six States

Through an arrangement with the Technical Committee of the Master Brewer's Association, the samples of barley grown in the season of 1935 and submitted under the rules and regulations of the Master Brewer's Association Barley Contest, were sent to the regional malting laboratory at Madison, Wisconsin, for experimental malting and analysis. While this study has supplied data of considerable interest in relation to methods of judging barley for evaluation of malting quality and the comparative value of these samples, as determined by barley and malt analyses, the results will be used in the present paper only in showing the influence of climatological and regional conditions upon the malting quality of the limited number of samples (44 barleys), of fairly representative varieties produced in six states. The Michigan samples, which were grown in a very localized area, had plumper berries than the samples from other states as indicated by their kernel weights. The kernel weight of the South Dakota samples was lowest, which was probably caused by the hot, dry weather and rust epidemic just prior to ripening. Barley samples from other states were intermediate as to kernel weight. In percentage of malt recovery considered on the air-dry basis of barley and malt, South Dakota had the highest with Iowa lowest, the other states being intermediate. The low recovery of malt in the Iowa samples may be associated with the higher percentage of blight. The data summarized in Figure 2 of malts produced from the barleys grown in the six states indicated relatively high extracts. The highest extract was obtained from a single sample of barley submitted from the state of Illinois; likewise this sample had high diastatic power which was apparently an unusual combination. The 10 malts from Michigan were highest in extract, the 5 malts from Iowa second, the 13 malts from Wisconsin third, the 10 from Minnesota fourth, and the 5 from South Dakota lowest.

In brief, the summary data show a relatively low protein content in barleys grown in 1935 and, in general, a high diastatic power. This was in contrast to the quality of the somewhat comparable barleys and malts produced in part of the same area during 1934 as shown by the following comparative data:

	Average composition Wisconsin farmers samples 1935	Average composition Wisconsin farmers samples 1934
Protein in malt, %	13.45	15.26
Sol. N. in wort × 6.25, %	4.37	4.54
Amount in relation to total protein, %	32.5	29.7
Extract dry basis, %	73.8	72.2
Diastatic power, ° L.	159	128
Moisture content of malt, %	5.5	4.2

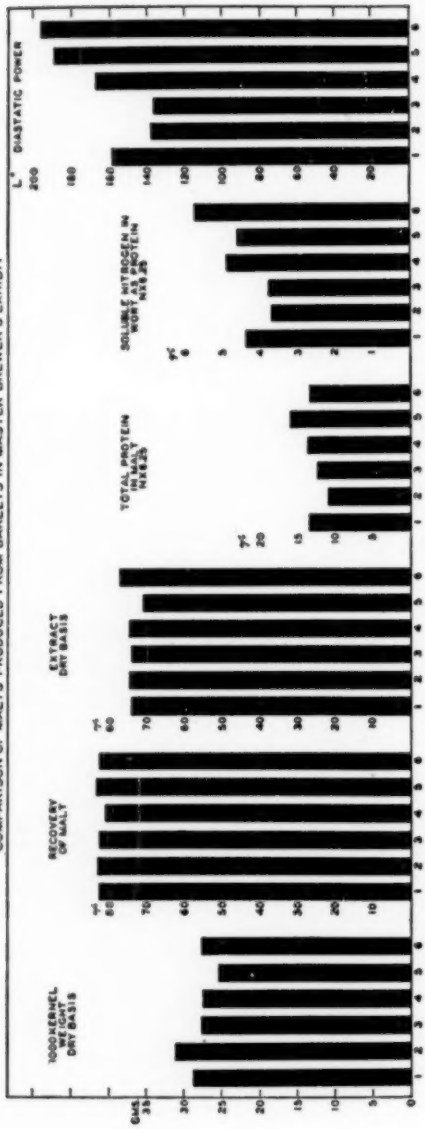
COMPARISON OF MALTS PRODUCED FROM BARLEYS IN MASTER BREWER'S EXHIBIT
1000 KERNEL WEIGHT DRY BASIS
RECOVERY OF MALT
EXTRACT DRY BASIS
TOTAL PROTEIN IN MALT N×6.25
SOLUBLE NITROGEN IN WORT AS PROTEIN N×6.25
L° DIASTATIC POWER

Figure 2. Graph showing the comparison of averages of the malts produced from the barleys grown in 1935 and received from the six states competing in the Master Brewer's barley contest. (1) Wisconsin, 13 malts; (2) Michigan, 10 malts; (3) Minnesota, 10 malts; (4) Iowa, 5 malts; (5) South Dakota, 5 malts, and (6) Illinois, 1 malt.

The total protein of the malts was, in general, lower than in 1934. The soluble nitrogen in the wort was lower, and the percentage of the total nitrogen soluble in the wort was somewhat higher than in malts produced from barleys grown during the previous season. The highest average diastatic power was found in the malts of barleys from South Dakota, although an individual sample produced in Illinois was higher than all of the state averages. The Iowa samples were second in diastatic power with the Wisconsin samples third, ranging higher than those from the Minnesota and Michigan barleys. In general this series of malts from the six states was in fair agreement with the malts produced from the uniform set of five varieties of barley grown at several stations in the same regions.

Comparison of Five Varieties of Barley Grown in Uniform Regional Series in 1935

The five varieties of barley grown in cooperation with the various experiment stations in connection with the coordinated barley quality program showed not only an interesting relation between the several barley producing regions, but also a difference in varietal reaction in smaller regions, as well as throughout the whole region.

Comparison of Barley Varieties from All Regions

The five varieties used in the uniform varietal series were grown under comparable conditions at each of the 11 experimental stations. The varieties used annually in this comparative series are: (1) Oderbrucker, Ped. 5-1, (2) Wisconsin Barbless, Ped. 38, (3) Velvet, Minn. 447, (4) Manchuria, N. D. 2121, and (5) Trebi. The barley samples were all shipped to Madison where they were malted under comparable conditions. With certain exceptions the varieties ranked in approximately the same order as in the results obtained in 1934. The average varietal differences in malt recovery, extract, total protein, soluble nitrogen in the wort, diastatic power, and moisture are shown graphically in Figure 3.

Comparison of Malts Produced from Barleys Grown in 1934 and 1935

Seasonal conditions in 1934 were very strikingly in contrast to those of 1935. The season of 1935 was much more favorable for the production of good quality barley with the exception of three stations where hot winds and rust caused relatively immature barley, especially at Brookings, South Dakota, and at Fargo, North Dakota. In the central or upper Mississippi Valley area, there was an excess of precipitation during the ripening period which resulted in considerable disease

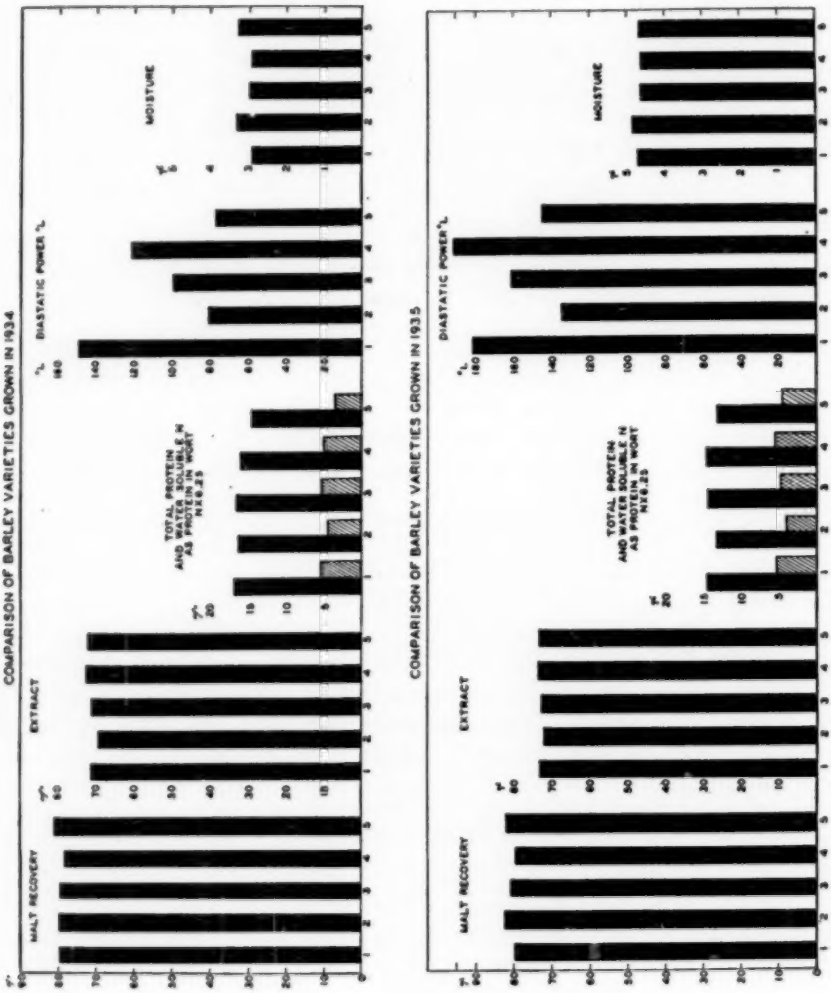
COMPARISON OF BARLEY VARIETIES GROWN IN 1934
MALT RECOVERY
EXTRACT
DIASTATIC POWER °L
TOTAL PROTEIN AND WATER SOLUBLE N AS PROTEIN IN WORT N X 6.25
MOISTURE
COMPARISON OF BARLEY VARIETIES GROWN IN 1935
MALT RECOVERY
EXTRACT
DIASTATIC POWER °L
TOTAL PROTEIN AND WATER SOLUBLE N AS PROTEIN IN WORT N X 6.25
MOISTURE

Figure 3. Graph showing the comparison of the malts from the five varieties of barley grown in the uniform regional series in 1934 and 1935. (1) Oderbrucker, Ped. 5; (2) Wisconsin Barbless, Ped. 38; (3) Minnesota Velvet; (4) Manchuria, N. D. 2121, and (5) Trebi.

damage. Further damage resulted when barley was harvested with high moisture content.

A comparison between the malts from the two seasons barley is given in Figure 3. The 1935 malts as compared with those of 1934 showed about the same malt recovery, except for Ped. 38 which was slightly higher in 1935. The extract yield of the malts from the 1935 crop averaged higher than those from the 1934 crop with the varieties keeping the same order as 1934. In some few locations in 1935 the extract on malts from certain of the varieties was unusually high for the six-rowed type of barley used. Total protein for all varieties was conspicuously lower in 1935 than for the previous year, with Oderbrucker and Manchuria being highest in 1935. The soluble nitrogen in the wort calculated as protein was generally lower in 1935, with Ped. 38 lowest, exchanging places with Trebi, the lowest of 1934. The percentage of the total nitrogen soluble in the wort was higher in all five varieties in 1935 than in 1934. The diastatic power was outstandingly higher in 1935 than 1934, which is seemingly in contradiction to the general opinion that high protein barleys produce correspondingly higher diastatic malts. The diastatic power of malts produced in the experimental malting unit would normally be higher on account of improved drying conditions; but this alone does not account for the greater diastase in 1935. It might be well to point out that commercially produced malts of 1934 were about 15° L. lower than 1935 malts. In diastase production all varieties changed positions from last year except Velvet. The Manchuria, N. D. 2121, placed first in 1935 while Oderbrucker was highest in 1934. Trebi and Ped. 38, low both years, changed position in 1935, with Trebi slightly higher than Ped. 38.

Comparison of Barley Varieties from Four General Areas

The locations at which the five barley varieties were grown have been divided more or less arbitrarily into four general regions; the central section including Madison, Wisconsin; East Lansing, Michigan; Waseca, Minnesota; Urbana, Illinois; and Columbus, Ohio, at which locations the reaction of the spring barleys, at least in the season of 1935, was relatively similar. Normally Iowa would be included in this section, but inasmuch as the samples from Emmetsburg and Kanawha, Iowa, were badly infected with blight the data from these stations have been omitted. The stations at Lincoln, Nebraska; Brookings, S. Dakota; and Fargo, N. Dakota, constitute the second general section where the reaction of the barleys and the composition of the malts made from the barleys were somewhat different from those of the central stations, especially in the season of 1935, because hot,

dry winds and rust prevailed just prior to the ripening period at the latter two stations. The third area, including Bozeman, Montana, and Fort Collins, Colorado, the intermountain section where the barleys were irrigated; and the fourth, Davis, California, where three varieties were grown in contrast with the so-called Coast type. The comparisons of the malts produced from the different varieties in these locations are presented in graphic form in Figure 4. This figure shows a number of comparisons of interest, although space will permit only

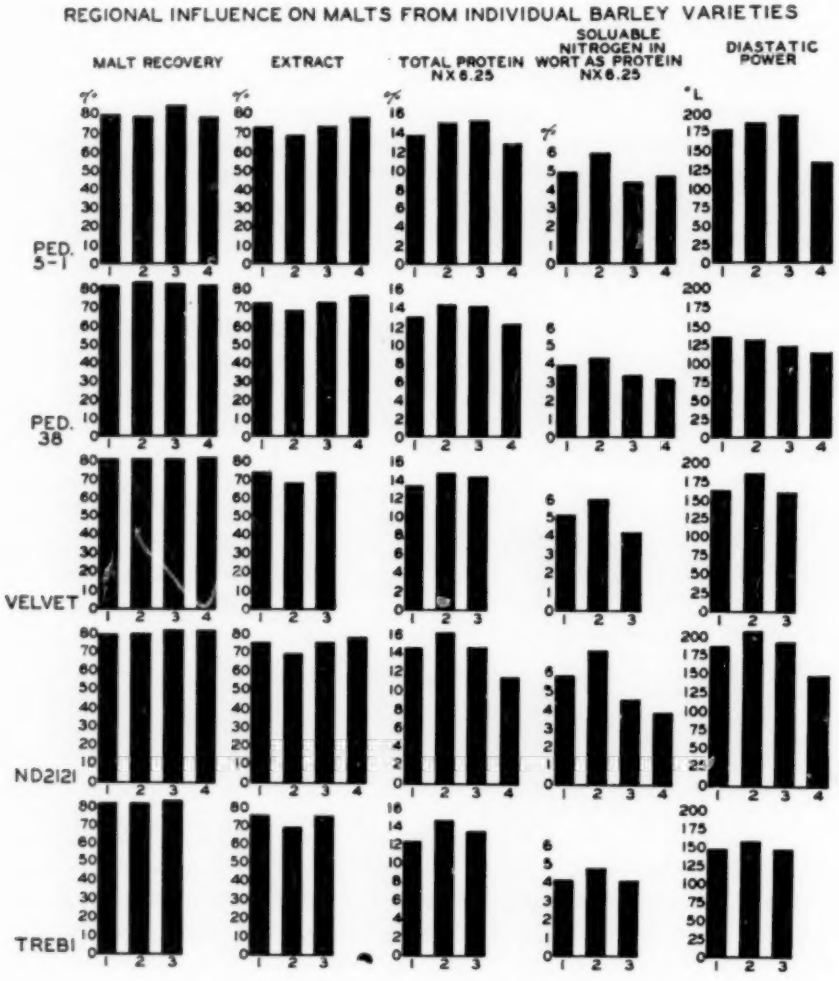

Figure 4. Graph showing the individual comparisons of the malts produced from the five barley varieties grown in the four general areas in 1935: (1) Average of malts from barleys grown at Waseca, Minn., Madison, Wis., East Lansing, Mich., Urbana, Ill., and Columbus, Ohio. (2) Average of malts from barleys grown at Lincoln, Neb., Brookings, S. D., and Fargo, N. D. (3) Average of malts from barleys grown at Fort Collins, Colo., and Bozeman, Mont. (4) Malts from barleys grown at Davis, Calif.

a few details of varietal response and the differential reactions of the varieties to the regions. It is interesting to note that Ped. 38 withstood drought conditions at Brookings and Fargo, producing plump kernels and good yields. Oderbrucker, Ped. 38, and Velvet varieties in 1935 seemingly were more affected in malting quality by the dry climate at these stations than Manchuria, N. D. 2121. Oderbrucker was distinctly higher in recovery of malt at the irrigated stations. Protein content was high in Manchuria, N. D. 2121, grown at Lincoln, Nebraska, Brookings, S. Dakota, and Fargo, N. Dakota, and in Oderbrucker grown at Fort Collins, Colorado, and Bozeman, Montana. Soluble nitrogen closely paralleled the protein content, with a very high percentage in Manchuria, N. D. 2121, at the drier stations of Lincoln, Brookings, and Fargo. Diastase content was highest at the stations in the drier area. Oderbrucker was higher in diastase at the irrigated stations, and Ped. 38 higher at the stations in the central section.

The regional influence upon the barley varieties in relation to malting and malt compositions perhaps is better shown by the average of all five varieties in the four regions mentioned above. In general all varieties throughout the whole region produced barley which malted more satisfactorily than in 1934, the exception to this being the varieties grown at Brookings and Fargo where the hot, dry winds resulted in a premature ripening. While the averaging of all varieties which react somewhat differentially to environmental conditions may be somewhat misleading, nevertheless the broader regional influences upon malting quality are shown by such an average. By examining Figure 5 which is a graphic summary of all varieties produced in the separate regions, it will be seen that the barleys grown at Lincoln, Brookings, and Fargo had highest total protein, soluble nitrogen in the wort as protein, and diastase, with lowest extract. Highest malt recovery was obtained from the barleys grown at Fort Collins and Bozeman in the irrigated area; otherwise these stations produced malts fairly comparable to that of the stations in the central section with the exception that total nitrogen was higher and soluble nitrogen lower at the irrigated stations. The malts from barleys grown at Davis, California, had highest extract and lowest diastase.

Discussion of Results

Certain phases of the investigations have been discussed in connection with the summary presentation of the data. Therefore, only a few general comments will be made in relation to the final summary of 1935 barley and malt investigations. Referring to varieties ordinarily used in malting there was evidence in the results of the 1935

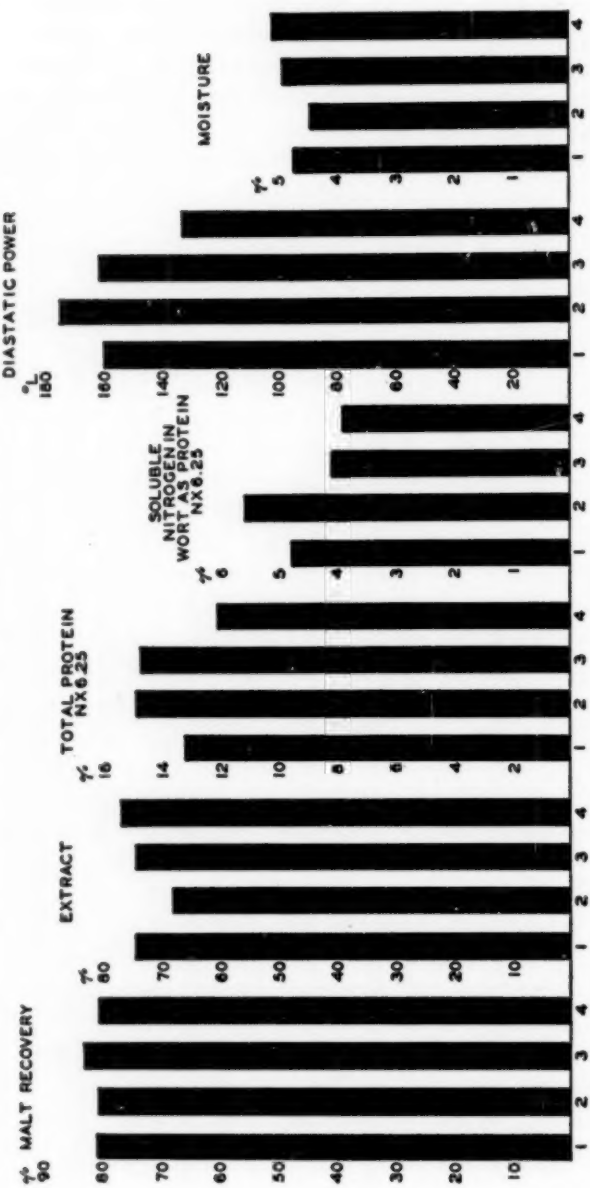

Figure 5. Graph showing the regional comparison of the malts produced from the barleys grown in the four regional areas. The average of malts produced from all five varieties grown at (1) Waseca, Minn., Madison, Wis., East Lansing, Mich., Urbana, Ill., and Columbus, Ohio; (2) Lincoln, Neb. ,Brookings, S. D., and Fargo, N. D.; (3) Fort Collins, Colo., and Bozeman, Mont., and (4) Davis, Calif.

barleys to suggest that Ped. 38 has a somewhat lower extract, lower soluble nitrogen in the wort, and lower diastatic power than other varieties. To a lesser extent this was true in the case of the Velvet variety. These results are in general confirmed by the data obtained on the 1934 crop. Studies of the Ped. 38 barleys and malts have shown a need of a relatively longer time in the steep to reach optimum moisture content, and have shown a relatively slower rate of growth at the same moisture content than either the Oderbrucker or Manchuria variety. To a lesser extent this is also true of Velvet. Preliminary investigations have been started with the idea of developing a method of malting to compensate for these differential varietal responses in malting, which, of necessity, count against certain varieties in a uniform procedure adapted more specifically for the Oderbrucker and Manchurian types of barley. These preliminary experiments have shown that with modified conditions a malt of much better quality is secured. For example, the Ped. 38 variety produced at Madison in 1935, which was a fairly good grade of barley at the outset, when malted under a certain set of conditions gave a more rapid growth, better modification of the endosperm mass, higher soluble nitrogen in the wort, and in general, higher diastatic power than when malted under the conditions used in the comparative series. Further investigations along this line of procedure are necessary before any conclusions can be drawn, or any recommendations made as to the differential malting procedures necessary to give the best results from any given variety.

TEMPERATURE EFFECTS IN THE PREPARATION OF WHEAT AMYLASES [1]

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Many workers have emphasized the necessity for maintaining the lowest possible temperatures during operations involved in the preparation of amylases from biological materials and products. Sherman, Caldwell, and Doebbeling [2] have observed this precaution even to the extent of using a mechanically cooled centrifuge in their precipitation procedures.

In attempting to identify and measure the factors governing diastasis in wheat flour, Sandstedt, Blish, Mecham, and Bode [3] found that the amylases can be almost quantitatively extracted from flour with 5% sodium chloride solution, from which they may then be precipitated with alcohol. Ammonium sulfate also precipitates amylase, as is well known. Facilities for performing all operations (especially centrifuging) at ice-water temperature were not always conveniently available. Under ordinary conditions no serious losses of enzymic activity were observed when the process was carried to completion without interruption at near room temperature. However, during extremely hot summer weather there were apparent losses in activity when preparations stood in contact with alcohol at room temperature for any considerable periods of time. It was thought advisable to make quantitative measurements of the effect of temperature upon rate of inactivation of wheat flour diastase, both in the presence and in the absence of ethyl alcohol.

Preparations Involving Alcohol

20 g. of a fairly high diastatic bakers' flour were extracted for 30 minutes (with frequent shaking) with 100 cc. of 5% sodium chloride at 0°, and the extract was removed with the centrifuge. 2 cc. aliquots were taken, and to each aliquot was added enough ethyl alcohol to make the final alcohol content 90% by volume. In each case both the

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[1] Published with the approval of the Director as Paper No. 189, Journal Series, Nebraska Agricultural Experiment Station.

[2] Sherman, H. C., Caldwell, M. L., and Doebbeling, S. E. Further studies upon the purification of properties of malt amylase. J. Biol. Chem. **104**: 501 (1934).

[3] Sandstedt, R. M., Blish, M. J., Mecham, D. K., and Bode, C. E. Identification and measurement of factors governing diastasis in wheat flour. Cereal Chem. **14**: 17–34 (1937).

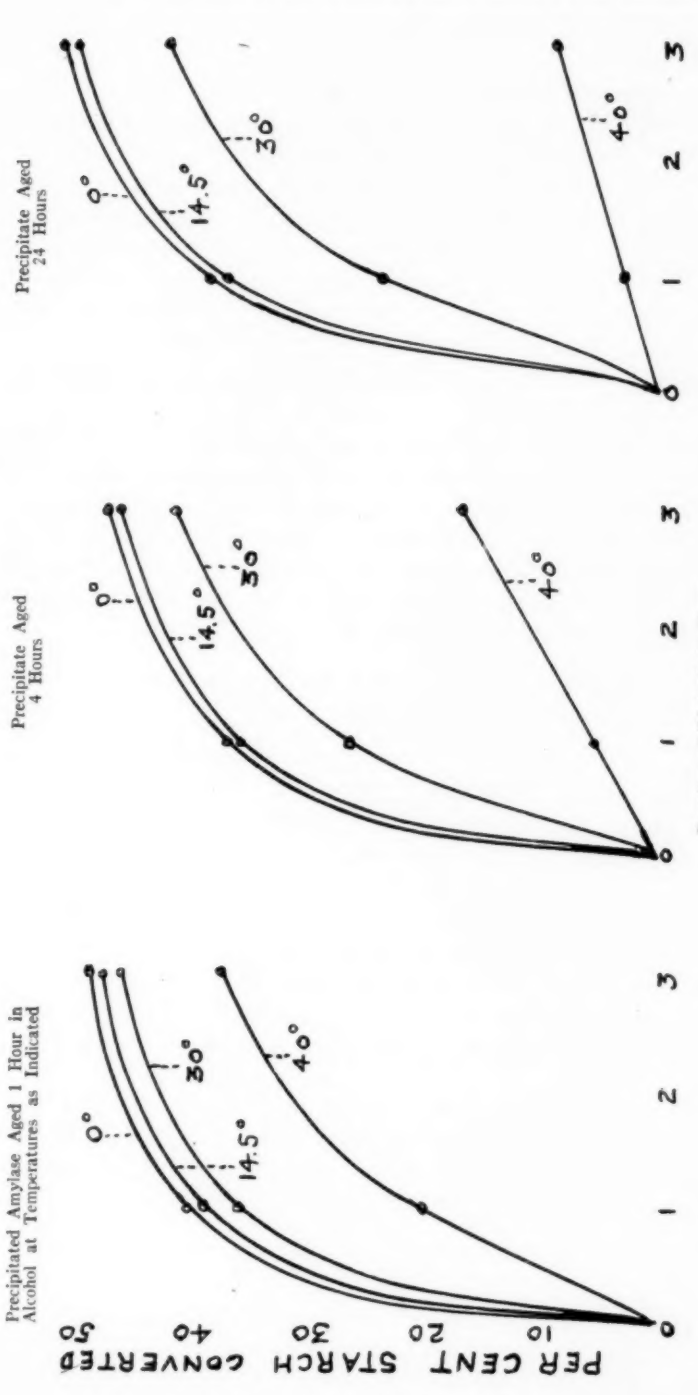

Figure 1. Effect of temperature and time on the inactivation of amylase by alcohol.

extract and the alcohol were brought to the specified temperature before mixing.

The temperatures selected for study were 0°, 14.5°, 30°, and 40°, respectively, and the amylase precipitates were kept in contact with the alcohol from which they were precipitated for 1 hour, 4 hours, and 24 hours, respectively, at the temperatures specified. Each precipitate was then separated from its liquid by means of the centrifuge, dispersed in 50 cc. of water, placed in a water thermostat at 30°, and mixed with 50 cc. of a 2%, solution of boiled wheat starch. 2 cc. aliquots were withdrawn at 1 and 3 hours, respectively, for maltose determinations by a ferricyanide reduction method.

The effects of both temperature and time are shown graphically in Figure 1.

The data presented in Figure 1 show quantitatively the extent to which time and temperature influence the destruction of flour amylase activity when the amylase is permitted to stand in contact with the strong alcohol from which it is precipitated. For short time intervals, under reasonably cool conditions, the degree of inactivation is slight. Substantial loss of activity can occur, however, over long time intervals at excessively high room temperatures.

Amylase Stability in the Absence of Alcohol

One of two aliquots of a 5% sodium chloride extract of flour (1 part flour to 5 of salt solution) was stored 24 hours at 6° C. while the other aliquot stood 24 hours at 40° C. At the end of the 24-hour period 2 cc. of the former, acting upon 100 cc. of 1% boiled wheat starch for 1 hour at 30° C. converted 48.0% of the starch into maltose. The latter, similarly tested, converted 46.5% of the starch.

Flour amylase was precipitated from aliquots of a 5% salt solution extract of flour by two-thirds saturation with ammonium sulfate. One such precipitate was stored overnight at 6°, the other at 30° C. The following morning both showed essentially the same activity (40.5 and 40% conversion, respectively, of boiled wheat starch in 1 hour at 30° C.).

These typical experiments indicate that, within a range of 0° to 40° C., in the absence of alcohol, and at a reaction near neutrality, flour amylase, either in dispersion or as precipitated by ammonium sulfate, is stable for many hours.

RELATION OF THE TWO SUGAR FORMING DIASTASES [1] TO THE LINTNER NUMBER

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(Received for publication June 16, 1936)

The dual nature of the sugar forming portions of the diastase of certain grains has recently been more clearly demonstrated by Teller (1936). As thus shown, the activity of each portion is materially modified by change in temperature and pH. At the higher temperatures of their activity and within suitable limits of pH values, the one diastase produces at a given temperature more maltose with the smaller pH; the other less. For example: at 60° C. the one type of diastase—that which predominates in wheat flour—will produce in a given time distinctly more maltose in a starch medium having a pH value near 4.5 than in a similar medium having a pH value near 6.2. With the other type of diastase—that which is characteristically developed during germination and which becomes segregated to a marked degree in the bran—the reverse is true.

This is clearly seen in the table showing the original data by which it was found. A consideration of this and other data shows that at any point as determined by pH and temperature, the amount of maltose produced in a given time is a resultant of the combined action of the two diastases. A small change in temperature or pH especially at certain points may produce a very material change in the relative activity of the two. The one may counter-balance or over-balance the other.

That small changes in acidity have a marked influence on the activity of diastase has been known for fifty years or more. Sherman and Thomas (1916) and later various others, have studied the effects of variations in pH on the amounts of sugar produced by diastase. Ohlsson (1922) applied differences in pH in such a manner as to show the presence of two diastases in malt. One he called saccharogenase, the other dextrogenase—incorrectly assuming the latter to be the liquefying enzyme. The influence of conflicting properties of the two sugar forming diastases as here noted seems to have been overlooked until their location in different parts of wheat was seen as in the results

[1] Diastase includes also a type which produces the well known liquefying action on starch. The distinctive properties of this amylase together with certain matters pertaining to it may best be discussed by themselves.

shown in the table and their properties under different conditions compared. In these properties we see something of the cause of the confusion and uncertainty that is so general throughout the voluminous literature on diastase. We also see a cause for much of the difficulties that have been experienced in determining the amounts of diastase in different substances.

TABLE I

DIASTATIC ACTIVITY OF UNGERMINATED AND GERMINATED WHEAT PRODUCTS. MALTOSE MADE IN DIFFERENT STARCH MEDIA BY THE DIASTASES ACTING AT DIFFERENT TEMPERATURES IN MEDIA OF DIFFERENT pH VALUES [1]

Temperature of digestion, °C.	Plain starch		1/20 mole sodium acetate starch		1/20 mole acetic acid, sodium acetate starch	
	Flour, mg. maltose	Bran, mg. maltose	Flour, mg. maltose	Bran, mg. maltose	Flour, mg. maltose	Bran, mg. maltose
	Marquis Wheat not germinated					
20	93	46	94	30	201	49
30	145	65	105	45	281	74
40	204	90	120	73	348	98
45	182	105	110	96	369	149
50	148	104	47	75	344	114
53	47	85	18	47	239	80
56	42	66	12	26	194	62
60	15	34	3	5	59	27
65	1	5	1	2	1	1
	Marquis Wheat, 96 hour germinated					
20	166	77	115	57	227	88
30	179	123	173	90	344	137
40	348	230	238	144	396	220
45	369	297	283	235	417	249
50	396	296	191	220	474	268
53	311	292	85	181	469	229
56	238	286	61	124	302	176
60	147	209	40	96	170	88
65	51	104	27	50	32	27

[1] 25 mg. each material digested in 5 cc. water at 20° C. for 1 hour; 50 cc. 2% starch paste at each required temperature added and digested for 1 hour; action stopped with sulfuric acid and sodium tungstate; maltose determined by ferricyanide method and calculated to milligrams in each tube.

Determined pH: plain starch near 6.2; sodium acetate starch near 6.7; acetic acid, sodium acetate starch near 4.5.

The various methods which have been used in attempts to compare the diastase in cereals and their products are all subject to the influences of temperature and pH of the media in which they work. These methods include those of Lintner (1886), Wohlgemuth (1908), and Rumsey (1922), and their several modifications. The Wohlgemuth method which depends on changes in color of iodine compounds does not show the amount of sugar production nor the entire diastase activity but is associated with changes which may be largely independent of these. The Rumsey method, used largely for studying the bread-

making qualities of flour, depends upon conditions which may be independent of the amount of diastase present. The Lintner method and its modifications is the only one which will be discussed at this time.

Some of the many modifications of the Lintner method are mentioned and in part described in Allen (1923 and 1930) and in Walton (1928). Others will be found in the bibliography of some of the large number of papers on this subject. The favorite procedure is to digest the finely powdered material in pure water for a chosen length of time and taking a selected amount of the clear filtrate, with or without dilution, for the determination. The many difficulties accompanying this need not be now enumerated. The selected portions of the solutions are next mixed with a prepared starch paste generally of 1 or 2% Lintner starch, with or without a buffer reagent in the solution. The mixture is digested at a chosen temperature, generally near 21° C. but in some instances at higher or lower temperatures. Sherman and associates (1910) selected 40° C. Oshima (1930) found with Takadiastase less variation with slight changes in temperature at 50° C. than at 40° C. Takadiastase does not contain that type of diastase characteristic of wheat flour but does contain the other sugar forming type. This higher temperature is near the average of the optimum temperature for the two types of sugar forming diastase found in wheat, barley, and rye. The results he found have been found for both types in various instances during the course of this work.

A comparison of the results at 20° C. in the above table with those at 50° C. and 53° C. for the four different materials in three types of starch paste show how misleading the results at 20° C. may be as an index to what may occur at other temperatures. In view of the extent to which the examination of malt for diastatic strength is made in certain industries, this becomes a matter of much importance. It is apparent that the method as now used does not give the facts that are sought. A nearer approach seems to lie in a selection of such temperature and pH value as to approximate a fair average condition. From a study of the above and other data, some of which are shown in my previous article (see Teller, 1936), this lies near 50° C. in a medium having a pH near 5.0. Further studies in connection with making and use of malt should fix this point more definitely.

In making the above and thousands of other determinations of maltose the method described by Blish and Sandstedt (1933) has been used with a large degree of satisfaction. The results are very concordant, the end point is definite and the titration is very simple especially when a 10 cc. universal pipette graduated in 10ths is used. It has often seemed that adjustment to larger quantities such as described by Coleman and associates (1934) but greater, would be helpful.

Summary

In certain cereals of which wheat is a convenient example, there are two types of sugar forming diastase, one of which is segregated in a relatively pure condition in normal flour, the other in the bran of germinating grain.

The properties of these two types are such that through a considerable range of pH and in the higher temperature of diastatic activity, a small change in either temperature or pH may cause the amount of sugar produced by one diastase to increase greatly while the amount produced by the other will decrease. Changes in the opposite direction will reverse the relative action of the diastases.

Largely because of these differences in properties in the two types of diastase, the so-called Lintner number, as now determined, is a poor index to the amount of diastase present in malt or the work it will do when subjected to the conditions under which it is generally used.

Accepting that no practicable method of accurately determining the amount of diastase present is now available, a more hopeful outlook for a close approximation lies in selecting a temperature and pH more nearly the average optimum for the two types. These are found to lie near 50° C. and near pH 5.0.

Recent modifications of the potassium ferricyanide method are well suited for determining the amount of maltose formed.

Literature Cited

Allen, A. H.
1923 Commercial Organic Analyses, 5th Edition, **1**: 176. P. Blakiston's Son & Co., Inc., Philadelphia, Pa.
1930 Commercial Organic Analyses, 5th Editiion, **8**: 159. P. Blakiston's Son & Co., Inc., Philadelphia, Pa.

Blish, M. J., and Sandstedt, R. M.
1933 An improved method for the estimation of flour diastatic value. Cereal Chem., **10**: 189–202.

Coleman, D. A., Snider, S. R., and Dixon, H. B.
1934 The diastatic activity of whole wheat and some other cereal grains as determined by the Blish-Sandstedt method. Cereal Chem., **11**: 523–531.

Lintner, Carl J.
1886 Studien über Diastase. J. prakt. Chem. N. F., **34**: 378–394.

Ohlsson, Erik
1922 Sur l'existence de deux ferments amylolytiques dans la diastase du malt. Compt. rend. soc. biol., **87**: 1183–1184.

Oshima, Kokichi
1920 A new technical method for estimation of the saccharogenic power of diastatic preparations. J. Ind. Eng. Chem., **12**: 991–993.

Rumsey, Louys, A.
1922 The diastatic enzymes of wheat flour and their relations to flour strength. Am. Inst. Baking Bull., **8**: 84.

Sherman, H. C., Kendall, E. C., and Clark, E. D.
1910 Studies of amylase. I. An examination of methods for determining diastatic power. J. Am. Chem. Soc., **32**: 1073–1086.

Sherman, H. C., and Thomas, A. W.
1916 Studies on amylases. VIII. The influence of certain acids and salts upon the activity of malt amylase. J. Am. Chem. Soc., **37**: 623.

Teller, G. L.
1936 Evidence concerning two types of plant diastase. J. Biol. Chem., **114:** 425–430.
Walton, R. P.
1928 A Comprehensive Survey of Starch Chemistry, **1:** 301. The Chemical Catalog Co., Inc., New York, N. Y.
Wohlgemuth, J.
1908 Über eine Neue Methode zur quantitative Bestimmung des Diastatischen Fermentes. Biochem. Z., **9:** 1–9.

EFFECT OF FERMENTATION, CERTAIN DOUGH INGREDIENTS, AND PROTEASES UPON THE PHYSICAL PROPERTIES OF FLOUR DOUGHS [1, 2]

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(Read at the Annual Meeting, June 1936)

Effect of Fermentation on Physical Properties of Doughs

During the fermentation process the gluten appears to mellow and soften into a pliable, easily extensible mass. Contrary to what is often assumed, the elastic properties of the gluten appear to continually decrease. Enzymatic changes also are taking place in the starch, although these are not usually considered to appreciably affect the physical properties of the dough.

It was felt that it would be of interest to follow the changes in stress readings in progressive fermentation by the method described by Bohn and Bailey (1936, 1936a). Difficulty was immediately experienced in knocking the gas out of the fermented dough, and unless this was done and the dough thus restored to something like its density on being mixed, the results would have little meaning. The procedure finally adopted consisted of placing the fermented dough back in the farinograph mixer and remixing for 5 minutes. All doughs (both fermented and unfermented) were subjected to the same mixing treatment. It is realized that this re-mixing after fermentation may alter the physical properties of the dough. Dough Formula No. 2 plus 1% malt flour was used in these tests.

The stress readings as recorded in Table I for a strong and a medium strength baking flour are found to decrease very greatly with fermentation. The readings on the medium strength flour are consistently lower

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[1] Paper No. 1441, Journal Series, Minnesota Agricultural Experiment Station.
[2] Condensed from a thesis presented to the Graduate School of the University of Minnesota by Leonard J. Bohn, in partial fulfilment of the requirements for the degree of Doctor of Philosophy, July, 1935.

Dough Formula No. 2

Flour	300 g.
Water	Sufficient to give consistency of 540 farinograph units
Yeast	3 %
Salt	2 %
Sugar	3½%
Shortening	2 %

than those on the strong flour. The results certainly support the view that fermentation has a mellowing effect upon the gluten and not one of developing the elastic properties of the dough. In the fermentation of a dough the mobility appears to increase and the elasticity to decrease.

TABLE I

EFFECT OF FERMENTATION (26° C.) UPON STRESS READINGS
(Stress readings corrected for area—grams per square centimeter)

Fermentation time	Stress 15 seconds	Stress 30 seconds	Stress 1 minute	Stress 2 minutes
hours	*g./cm.²*	*g./cm.²*	*g./cm.²*	*g./cm.²*
		Strong flour		
0	27.4	20.7	16.9	14.0
1	16.4	12.6	10.6	8.6
2	13.0	10.0	8.3	7.0
3	10.2	8.1	6.8	5.7
		Medium strength flour		
0	17.6	13.1	10.0	8.9
1	10.2	7.3	5.7	4.7
2	6.9	5.1	4.0	3.3
3.5	4.3	2.8	2.2	1.8
5	2.8	2.1	1.8	1.6

Effect of Salt on Physical Properties of Doughs

Salt (NaCl) has a very marked effect upon the colloidal properties of a dough. The properties of a loaf of bread are decidedly improved as the salt content is increased up to about 2%. The upper limit which determines the amount of salt that it is desirable to use is set by the taste of the product. It appears to be common practice to use around 1¾% salt in white bread, 2% salt in whole wheat bread, and up to 2½% salt in rye breads.

The effect of salt on the stress readings after 0 and 3 hours fermentation of doughs prepared from medium strength flour is shown in Table II. The data are shown graphically in Figure 1. The addition of salt to a dough markedly increases the stress values obtained both before and after fermentation. The rate of change in stress readings

TABLE II

EFFECT OF SALT (NaCl) ON STRESS READINGS (MEDIUM STRENGTH FLOUR)

Salt	Width of farinograph curve	Height of farinograph curve	Stress 15 seconds	Stress 30 seconds	Stress 1 minute	Stress 2 minutes
%	*cm.*	*units*	*g.*	*g.*	*g.*	*g.*
			No fermentation			
0	1.3		9.9	7.6	6.0	4.8
1	1.4		15.6	12.2	10.0	8.1
2	1.6		16.8	12.9	10.8	8.9
			3 hours fermentation at 26° C.			
0		405	7.8	6.3	4.7	3.6
1		370	9.6	7.3	5.7	4.7
2		405	10.4	7.8	6.2	5.1

is especially great between 0 and 1% salt and less between 1 and 2%. The width of the farinograph curve also is increased by the addition of salt, assuming the height of the farinograph curve to be the same.

Salt, therefore, appears to toughen or strengthen the dough, presumably through its effect upon the gluten. This is accompanied by the mellowing or softening due to fermentation, which in some way prevents the cell walls from breaking down and forming large holes. It is possibly the toughening of the gluten due to salt which accounts for the

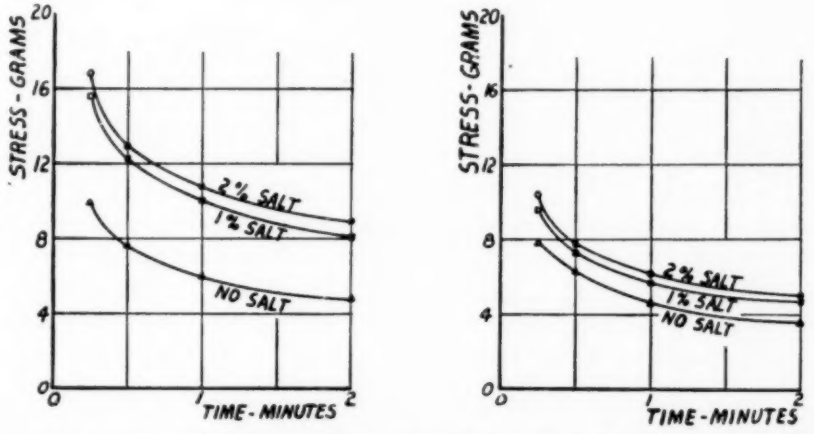

Figure 1. Stress readings in grams of doughs directly from the mixer (left) and after 3 hours fermentation at 26° C. (right), containing 0.1% and 2% of common salt (sodium chloride) respectively.

smaller volume of loaf, the improvement in grain, texture and color, and the smoother break and shred of a loaf with 2% salt as compared with one containing no salt.

Effect of Shortening on Physical Properties of Doughs

Shortening agents in the form of lards, compound shortenings, hydrogenated oils, butter, and other edible fats and oils, have a marked effect upon bread characteristics. The action appears to be physical, not chemical. They appear to act as lubricating agents which allow the gluten strands to stretch past each other and the starch particles with less resistance, and thus have greater freedom of movement.

As the percentage of shortening in dough is increased, the time required to reach the maximum point on the farinograph curve becomes longer. Moreover, the rate of rise on the farinograph curve tends to be slower. Table III shows the stress effects of different percentages of shortening in doughs made from strong flour after 0 and 3 hours fermentation respectively.

TABLE III

EFFECT OF DIFFERENT PERCENTAGES OF SHORTENING ON STRESS VALUES OF DOUGHS (STRONG FLOUR)

Shortening	Time to maximum height of farinograph curve	Maximum height of farinograph curve	Stress 15 seconds	Stress 30 seconds	Stress 1 minute	Stress 2 minutes
%	*minutes*	*units*	g.	g.	g.	g.
			No fermentation			
0	14	580	22.1	16.3	13.5	11.2
2	15	560	21.5	15.8	13.0	10.7
4	17	550	18.2	14.0	11.4	9.4
6	16	545	17.0	13.1	10.7	8.7
			3 hours fermentation at 26° C.			
0		440	11.5	8.4	6.6	5.7
2		415	11.7	8.5	7.0	5.7
4		400	10.2	7.4	5.9	4.6
6		425	11.6	8.6	6.9	5.6

Table IV shows the effect of different percentages of shortening in doughs made from medium strength flour after 0 and 3 hours fermentation respectively.

The addition of shortening to the unfermented dough is thus seen to decrease the stress readings and thus appears to bear out the contention that shortening acts as a lubricant. Four per cent caused a greater decrease than 2%, and 6% more than 4%.

The stress readings at the end of 3 hours fermentation did not show any consistent trend. The higher shortening doughs felt and appeared as though they should have the lower stress and farinograph readings, but this was not the case.

TABLE IV

EFFECT OF DIFFERENT PERCENTAGES OF SHORTENING ON THE STRESS VALUES OF DOUGHS (MEDIUM STRENGTH FLOUR)

Shortening	Time to maximum farinograph reading	Maximum height of farinograph reading	Stress 15 seconds	Stress 30 seconds	Stress 1 minute	Stress 2 minutes
%	*minutes*	*units*	g.	g.	g.	g.
			No fermentation			
0	10	590	18.2	13.9	11.3	9.4
2	10	570	16.8	12.7	10.3	8.3
4	12	560	15.1	11.1	8.6	6.8
6	14	560	14.1	8.9	7.6	6.0
			3 hours fermentation at 26° C.			
0		440	10.5	8.3	6.4	5.2
2		410	9.0	6.3	4.9	4.0
4		440	12.1	8.7	6.7	5.2
6		425	11.3	7.6	5.8	4.6

Effect of Milk Powders on Physical Properties of Doughs

The quality or baking characteristics of milk powders varies greatly with the type of preheating or superheating which the milk receives prior to drying. The quality of the milk powder is also affected by the way the milk powder is manufactured. The milk may be condensed prior to going to the sprayers or rollers, or it may be sent direct. The condition of the milk prior to processing (acidity, bacterial count) has also an effect upon baking quality as found in bread.

A " good " grade of preheated milk powder made preferably by the spray process and from a good grade of milk, when used at a 6% level in bread, improves the volume, grain, texture, and the eating and keeping qualities of the bread. If the conditions are not optimum in all respects a " medium " grade milk powder will be produced which may

not improve the properties of the freshly baked loaf at all when used at a 6% level of dry milk solids not fat. The keeping quality may be improved, however, and thus the eating properties. " Poor " milk powders from a bread baker's standpoint may impair the physical and eating qualities at a 6% milk solids level. In the latter case the volume is

TABLE V

EFFECT OF DIFFERENT QUALITIES OF MILK SOLIDS NOT FAT UPON THE STRESS VALUES OF DOUGHS

Milk solids not fat	Grade of milk powder	Stress 15 seconds	Stress 30 seconds	Stress 1 minute	Stress 2 minutes	Optimum mixing time in farinograph
%		g.	g.	g.	g.	*minutes*
		Strong flour—no fermentation				
0		17.3	13.6	11.3	9.2	15
6	Good	14.4	11.1	8.7	6.8	21
6	Medium	11.7	8.4	6.2	4.6	20
6	Poor	9.5	6.5	4.6	3.2	19
		Strong flour—3 hours fermentation at 26° C.				
0		9.4	7.0	5.6	4.5	
6	Good	10.7	8.4	6.8	5.6	
6	Medium	8.8	6.3	4.8	3.5	
6	Poor	7.9	5.5	4.2	3.2	
		Medium strength flour—no fermentation				
0		17.6	13.8	11.2	9.4	10
6	Good	10.8	10.8	6.9	5.6	15
6	Medium	8.6	8.6	5.4	4.5	13
6	Poor	6.7	6.7	4.0	3.3	10
		Medium strength flour—3 hours fermentation at 26° C.				
0		11.3	8.8	6.9	5.8	
6	Good	8.7	6.5	5.1	4.1	
6	Medium	7.6	5.4	4.0	3.2	
6	Poor	4.4	3.1	2.3	1.9	

usually decreased and the grain tends to be open (though uniform) with thick cell walls. In the stress tests shown in Table V three milk powders falling into the above classes were chosen for the experiments. Strong and medium strength flours were used. The milk powders were classed as of good, medium, and poor quality, as judged by baking tests

and farinograph curves. Good milk powders require an appreciably higher absorption in bread than poor milk powders. The water-imbibing properties of the milk proteins are probably different.

It will be noted from Table V that the addition of milk powder, regardless of the quality, decreases the stress readings of unfermented dough. The poorer the quality of the milk powder the lower the stress readings. Even though good milk powder decreases the stress readings the quality of bread produced is usually improved. Shortening and malts have the same effect, but may improve bread quality also if used properly. Bread fermentation is really a process in which the stress values of the dough are lowered. It is possible that we do not desire highly elastic or rigid properties in the properly fermented dough.

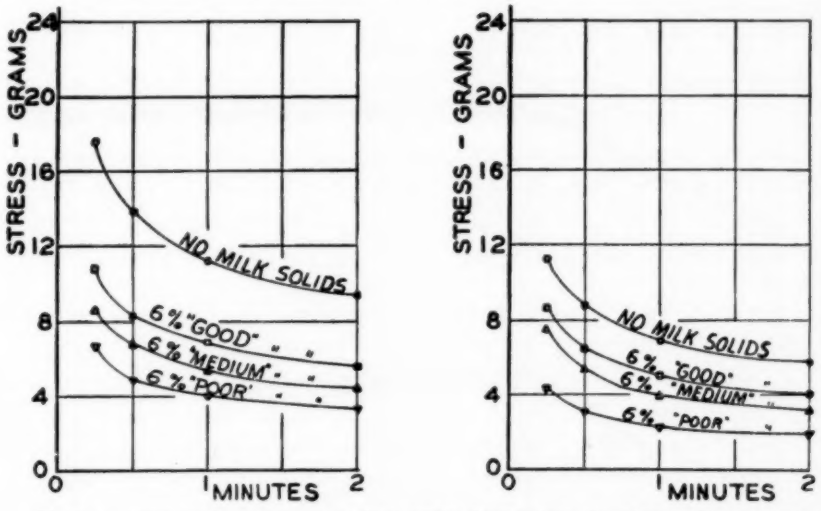

Figure 2. Stress readings in grams of four doughs directly from the mixer (left) and after 3 hours fermentation at 26° C. (right), and containing 0% milk solids, and 6% of "good," of "medium," and of "poor" quality of milk solids not fat respectively.

Table V shows that, in the case of strong flour, fermented doughs containing a good grade of milk powder gave a higher stress reading than the doughs with no milk. In the case of medium strength flour, all milk powder doughs gave lower stress readings after fermentation than the doughs without milk, the poorer milk powder showing lower results than the good milk powder. Figure 2 shows the effect of good, medium, and poor milk powders on stress readings using medium strength flour.

Doughs containing 6% good quality milk powder are easier to mold and more pliable than non-milk doughs. The lower stress readings of unfermented milk doughs probably account for this and the softer, mellower feel of the dough.

Comparing the milk doughs by themselves, the high quality "good" milk powder gives appreciably higher stress readings than the medium and poor grade milk powders. There appears to be a strength factor in milk powders something similar to that in flours.

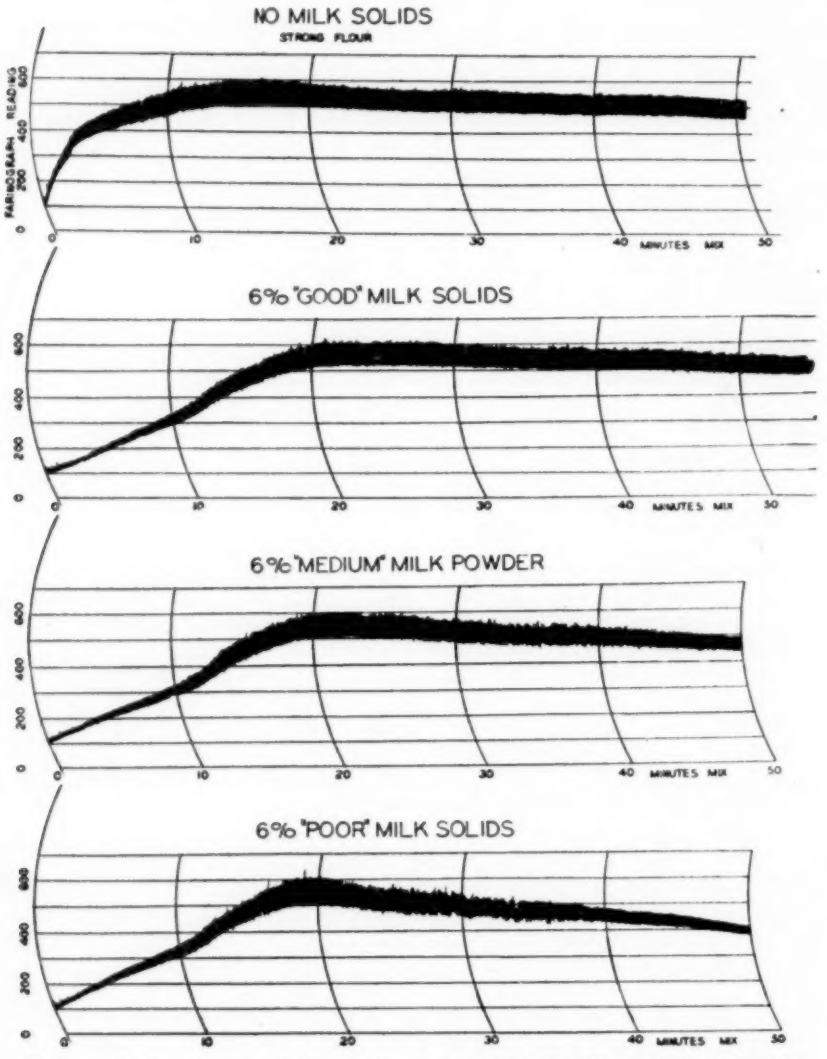

Figure 3. Farinograph curves of four doughs containing 0% milk solids, and 6% of "good," of "medium," and of "poor" quality of milk solids not fat respectively.

Figure 3 shows the effect of different qualities of milk powder upon the form of the farinograph curve as shown by strong flour, Formula 2 being used, the temperature of dough being 26° C.

The milk doughs were found to require a longer time to reach a maximum point on the farinograph curve than the doughs without milk. In the case of good milk powder the required mixing time was increased about one-third with both strong and medium strength flours. In the case of the poor milk powder the increase in mixing time over that required by the dough without milk powder was about 3 minutes in the case of strong flour and no increase in the case of medium strength flour. The baker can again detect these differences by the feel of the dough, although less accurately or quantitatively than with a farinograph.

The manner in which the farinograph curves rise and fall with the different qualities of milk powders shows how unstable poor milk powders are to prolonged mixing, whereas the good milk powders are relatively stable. Farinograph curves are thus used as an index of milk quality.

Effect of Enzyme Preparations on the Physical Properties of Doughs

It has been known for many years that certain diastatic and proteolytic enzyme preparations added to flours deficient in these enzymes improve the quality of the baked loaf of bread. Proteolytic enzymes appear to mellow or soften the proteins in the process of breaking down the proteins to smaller units. Diastatic enzymes break down the starch to dextrins and finally to maltose.

Many cereal chemists and bakers speak of malt preparations added to flour doughs as making the dough "more elastic and pliable." In reality, the doughs appear to be made more readily stretchable, less elastic and more pliable. The elastic properties of the dough are being decreased by the addition of enzyme preparations as indicated by the work to be described using a papain preparation, a barley malt extract, and a malted wheat flour, added to flour doughs.

PAPAIN.—Balls and Hale (1936) indicate that the first action of such proteinases as papain is coagulating, whereas larger additions of the enzyme produce liquefaction. They postulated that the first action makes the gluten more tenacious, whereas large additions of papain are detrimental and cause liquefaction.

A sample of the enzyme papain prepared by Parke Davis and Company (3024274) was used in the following experiments. It was described as a vegetable digestive ferment from the fruit juice of the papaw (Carica papaya Lin.), capable of digesting proteins in alkaline, neutral or slightly acid media. Ten, twenty, and thirty milligrams respectively of this preparation were dissolved in water just prior to mixing 300 g. of flour using bread Formula 2. The effect on stress readings is shown in Table VI and in Figure 4.

TABLE VI

THE EFFECT OF DIFFERENT AMOUNTS OF PAPAIN ON THE STRESS READINGS OF FLOUR DOUGHS (MEDIUM STRENGTH FLOUR)

Papain per 300 g. flour	Farinograph reading, maximum	Farinograph reading, 5 minutes	Stress 15 seconds	Stress 30 seconds	Stress 1 minute	Stress 2 minutes
mg.			*g.*	*g.*	*g.*	*g.*
No fermentation						
0	537		16.9	13.2	10.8	8.6
10	545		16.9	13.1	10.7	8.7
20	540		15.7	12.5	10.0	8.1
30	545		12.1	9.2	7.1	5.3
Three hours fermentation at 26° C.						
0		395	11.2	8.4	6.8	5.5
10		418	11.5	8.6	6.9	5.6
20		405	6.0	4.5	3.5	2.8
30		245	Very sloppy			

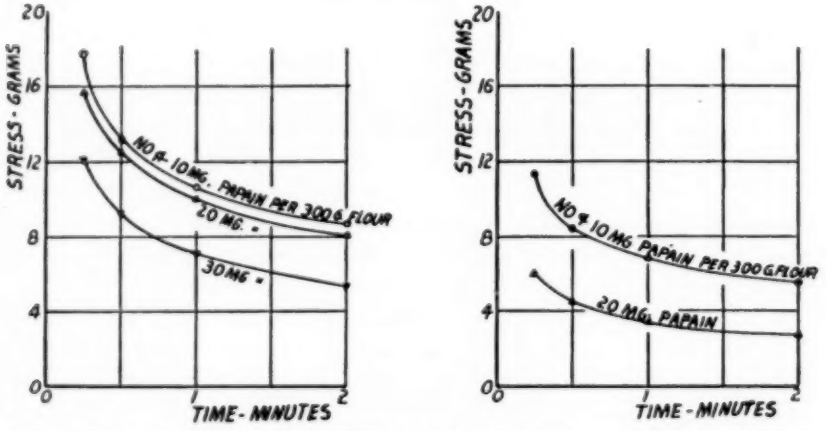
STRESS - GRAMS
TIME - MINUTES
NO # 10 MG. PAPAIN PER 300 G FLOUR
20 MG. "
30 MG "
STRESS - GRAMS
TIME - MINUTES
NO # 10 MG PAPAIN PER 300 G FLOUR
20 MG. PAPAIN

Figure 4. Stress readings of doughs directly from the mixer (left) and after 3 hours fermentation at 26° C. (right), and containing no added papain, 10 mg., 20 mg., and 30 mg. of papain per 300 g. flour respectively.

The addition of 10 mg. of papain was not found to appreciably alter the stress readings as compared with the control sample containing no papain. It is possible that this amount of papain only causes the coagulation of the protein spoken of by Balls and Hale, higher amounts of papain producing a degradation of protein. Twenty milligrams of papain was found to slightly lower the stress readings on the unfer-

mented dough, whereas after 3 hours fermentation at 25° C., the stress readings were greatly lowered. Thirty milligrams of papain greatly lowered the stress readings of the unfermented dough and the fermented dough was so sloppy that no attempt was made to take stress readings.

Rupp (1935) has studied the effect of papain on doughs by means of the farinograph and has found that small percentages of papain do not alter the farinograph curves. At least there is no evidence of a degradation of proteins. With higher levels of papain there was evidence of such an effect. This again might be considered as substantiation of Balls and Hale's hypothesis that the first effect of papain was coagulating and that larger amounts or a longer time produced a break down of protein.

MALT EXTRACT.—Malt extract is frequently added to flour doughs to supplement flours deficient in diastatic or proteolytic activity. Table VII shows the effect of different percentages of 72° Lintner diastatic malt extract on the stress readings of medium strength flour doughs.

TABLE VII

THE EFFECT OF DIFFERENT PERCENTAGES OF DIASTATIC MALT EXTRACT (72° L.) UPON THE STRESS READINGS OF DOUGHS MADE FROM MEDIUM STRENGTH FLOUR

Malt extract (72° L.)	Farinograph reading, maximum	Farinograph reading, 5 minutes	Stress 15 seconds	Stress 30 seconds	Stress 1 minute	Stress 2 minutes
%			g.	g.	g.	g.
No fermentation						
0	540		17.1	13.3	10.8	8.8
0.5	540		16.9	13.2	10.8	8.6
1.0	548		16.9	13.2	10.8	8.6
2.0	540		15.8	12.0	9.7	7.8
3 hours fermentation at 26° C.						
0		403	10.9	8.3	6.6	5.3
0.5		358	9.2	6.8	5.4	4.5
1.0		375	9.2	6.7	5.3	4.4
2.0		390	9.6	6.9	5.5	4.4

The addition of ½ to 1% of malt extract is seen to have no effect upon the stress readings of unfermented doughs. The addition of 2% malt did lower the stress readings slightly.

The fermented doughs with added malt extract were all lower in

stress readings than the sample without malt. The fermented dough with 1% malt appeared and felt appreciably slacker and stickier than the dough with 0.5% malt, yet there was no difference in the stress readings. In fact, the 5-minutes farinograph reading was slightly higher, though this might be expected with sticky doughs. The fermented dough with 2% malt was decidedly slack although the 5-minute farinograph and the stress readings were not lower, as would be expected, but slightly higher than the doughs with lower malt contents.

MALTED WHEAT FLOUR.—The addition to flour of definite though small amounts of sprouted wheat flour is used to supplement diastatic activity and thus ensure adequate gas production and a proper conditioning of the dough. The sprouted wheat flour used in the stress experiments to be described had an activity of 1620 Blish units and an original maltose content of 545 mg. per 10 g. of flour. Doughs made from medium strength flour were treated with 0, 0.5, 1.0 and 2.0% of malted wheat flour and stress readings were obtained as shown in Table VIII and Figure 5.

TABLE VIII

EFFECT OF DIFFERENT PERCENTAGES OF MALTED WHEAT FLOUR UPON THE STRESS READINGS OF FLOUR DOUGHS (MEDIUM STRENGTH FLOUR)

Malt flour	Farinograph reading, maximum	Farinograph reading, 5 minutes	Stress 15 seconds	Stress 30 seconds	Stress 1 minute	Stress 2 minutes
%			g.	g.	g.	g.
No fermentation						
0	553		17.4	14.3	11.9	9.6
0.5	540		16.8	13.5	11.0	9.1
1.0	543		16.0	12.7	10.4	8.6
2.0	545		14.4	11.2	9.1	7.2
3 hours fermentation at 26° C.						
0		405	11.1	8.6	6.9	5.7
0.5		370	7.4	5.6	4.5	3.7
1.0		355	8.0	5.8	4.8	3.9
2.0		363	8.0	5.9	4.8	3.9

The stress readings for unfermented doughs were found to decrease with increase of malted wheat flour added.

In the case of the fermented doughs the addition of malted wheat flour appreciably lowered the stress readings. Although the doughs with 1 and 2% malted wheat flour were evidently stickier and mellower

than the fermented dough with 0.5% malt flour, this does not show up in either the stress or the 5-minute farinograph readings. This phenomenon was also observed in the case of diastatic malt extract.

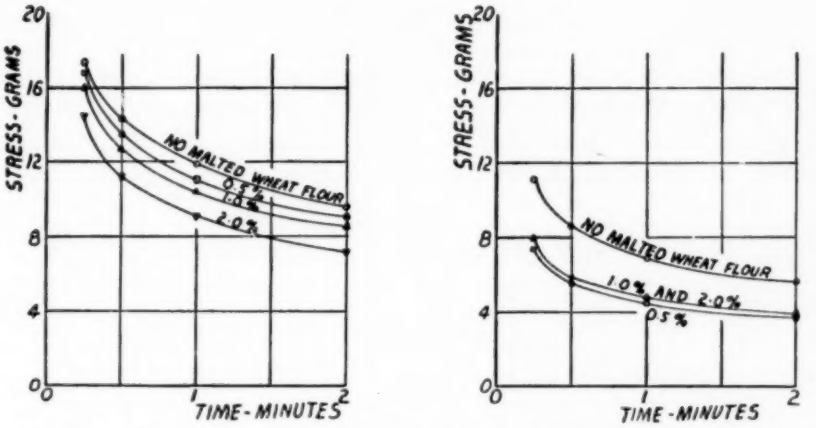

Figure 5. Stress readings in grams of four doughs directly from the mixer (left) and after 3 hours fermentation at 26° C. (right), and containing 0%, 0.5%, 1%, and 2% of malted wheat flour respectively.

It would thus appear that one of the objects of adding diastatic malt preparations to flour doughs is to soften or mellow the gluten. It has not been proven that the softening effect is entirely due to the papainase enzyme present in flour. It is possible that other enzymes, proteolytic, diastatic and otherwise, may also be partly responsible for the mellowing effect. It is difficult to obtain pure proteolytic enzymes free from amylases and *vice versa,* and thus the problem as to what enzyme or enzymes cause the softening effect upon the gluten or dough system remains unsolved.

Summary

Fermentation decreased the stress readings of flour dough, indicating that the yield point and elastic properties of the dough decrease and the mobility increases.

Sodium chloride markedly increased the stress readings and increased the width of the farinograph curve, indicating that it has a toughening effect upon the gluten.

Shortening, within limits, slightly decreased the stress readings bearing out the idea that it acts as a lubricant in bread dough.

Milk solids *not fat* markedly decreased stress readings after mixing, and increased the time of mixing required to reach optimum development as shown in the farinograph. Good quality milk powders appear

to make a greater contribution to "strength" and gave higher stress readings than poor quality milk powders, as well as showing greater tolerance to mixing.

Enzyme papain preparation did not affect stress readings when added to dough in small amounts. Larger additions appreciably decreased stress readings. This agrees with the hypothesis that small additions of papainase act as a coagulant upon wheat proteins, whereas larger amounts are liquefying. Barley malt extract and malted wheat flour decreased the stress readings of fermented doughs, and appear to decrease the elastic and increase the mobile properties of dough.

Literature Cited

Balls, A. K., and Hale, W. S.
1936 Proteolytic enzymes of flour. Cereal Chem. **13:** 54–60.
Bohn, L. J., and Bailey, C. H.
1936 Elasticity of wheat flour dough. Cereal Chem. **13:** 389–409.
1936a Effect of mixing on the physical properties of dough. Cereal Chem. **13:** 560–575.
Rupp, E. G.
1935 Effect of protease increments on the dough plasticity. Master's thesis filed in the library of the University of Minnesota, Minneapolis.

STUDIES ON TEST BAKING. I. THE TECHNIQUE AND SOME FACTORS AFFECTING FERMENTATION[1]

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Introduction

As the proof of the pudding is in the eating, so the proof of the flour is in the baking. Many scientific tests have been devised which are helpful in enabling one to assess the value of individual flour characters, such as maltose figures, gassing capacities, and so on, but the ultimate test of whether a flour is satisfactory or not is its behaviour in the bakehouse. It is comparatively easy for the miller to control such characters as maltose figure, protein content, colour, and gassing quality of his flour, and the importance of such control is generally appreciated. These factors, however, are subsidiary to baking quality proper. Maltose figure, for example, must not be too high, or the loaves will not bake or "soak." Rate of gas production must not be too low or small, or stodgy, unappetising loaves will result. At the same time, the quantity of gas given off in final proof does not determine the size of the loaf; it is rather a necessary condition for the production of a large loaf. It is obvious that a large loaf cannot result if gas production during proof is inadequate. Sufficient gas must be produced; then, *if the other contributing factors are present*, a loaf of large volume, and satisfactory in other characters, may be made. These other contributing factors are associated with the gluten, and constitute what may be regarded as baking quality proper. Many short and easy "strength" tests have been devised for testing gluten quality in the hope of eliminating the cumbersome baking test. None has proved satisfactory, and the only practicable means of testing baking quality proper is still the baking test. This test is difficult as well as cumbersome, and, so far, it has successfully resisted all attempts at strict standardisation. In theory, the baking test should undoubtedly conform as closely as possible to the technique of commercial baking. This, however, is a counsel of perfection. With many thousands of small hand-bakeries scattered throughout England, there are almost as many commercial techniques as there are bakeries. Dough

[1] Issued for private circulation in 1930 as Confidential Report No. 15 of the Research Association of British Flour-Millers. Released for publication by the Council of the Research Association, 1935.

temperature, percentage of yeast and of salt, length of fermentation and of final proof, extent of kneading of the doughs, and many other factors vary from bakery to bakery. Tinned loaves, cob loaves, cottage loaves, and the so-called "split batches" may be made, while in some parts of the country the further complication of home baking has to be considered. How can the technique of test baking be made to conform to commercial practice?

In America the problem is simpler than it is in Great Britain. An American miller may deal with one type of wheat throughout the year, such as Hard Spring or Hard Winter wheat. The flour may be sold on guaranteed protein and ash contents, while the dominance of the machine bakery necessarily concentrates attention on the quality of the loaf rather than on the behaviour of the dough. American cereal chemists are meeting the situation by making very small test loaves from, say, 100 g. of flour, under conditions that are gradually being standardised, thereby reducing the human element to the lowest possible degree. The characters of the resulting loaves—volume, grain, colour, *etc.*,—are assessed by a system of bakers' marks. Dough behaviour, apart from mere length of fermentation, is largely neglected in this system of test baking. With such small doughs, no knowledge at all can be gained of dough stability—perhaps the most important dough character in England where cobs and cottage loaves are still commonly made—and very little of dough "body."[2] The English baker wishes to know how his doughs will "handle," the American, what kind of bread he is going to obtain. The English baker, of course, is also interested in his bread, but it is hardly too much to say that if the dough handles well, if absorption, "body" and stability are satisfactory, and the dough "works" (*i.e.*, rises) well, satisfactory bread will usually result. Poor bread can usually be suspected in the dough stage. This does not mean that the loaf should be neglected entirely; sometimes a flour bakes out better than its behaviour in the dough would lead one to expect, and sometimes the reverse is true. In England, however, greater emphasis is laid on dough characters than on the loaf. And, probably, dough behaviour—or misbehaviour—is the cause of more complaints from bakers than is the character of the bread.

These considerations lead to a number of fairly obvious principles to be observed in test baking:

1. Loaves of commercial size should be made, *i.e.*, doughs should be scaled at $2\frac{1}{4}$ lb. This facilitates the judging of dough and loaf characters, and especially of dough body and stability.

[2] For an explanation of "body" see paper No. III of this series—"The Human Factor in Test Baking—A Psychological Study," by David Katz (in press).

2. It is neither possible nor desirable to eliminate the human element, but this element must be one of skill and experience, and must be controllable. The work should be done by a highly skilled and experienced baker who, in virtue of his skill and experience, is able to draw correct conclusions from his work.

3. The element of craftsmanship must be reduced to a minimum. In particular, the desire of the practical man, with an interest in his work, to turn out a beautiful product, a first-class loaf, from indifferent raw material, in other words, his desire to get the best possible results out of the raw material available, must be ruthlessly restrained. It is not the best loaf that is required in test baking. For example, the object may be to compare the behaviour of a set of flours under precisely similar conditions, and the conditions are no longer precisely similar if greater craftsmanship is brought to bear on the inferior material. This is, no doubt, an obvious principle, but it is necessary to bear it always in mind in dealing with the practical man. This is also an argument against the use of cottage loaves alone in test baking; cottages involve not only more precise control of oven conditions to avoid misshapen loaves, but also greater craftsmanship. Cob loaves and, for certain purposes, tinned loaves are preferable.

4. It follows from principles 2 and 3 that as many as possible of the factors and details of test baking technique should be standardised so as to reduce to a minimum the scope of the necessary human element, and we should be able to express dough and loaf characters in quantitative terms that are independent of our personal judgments. This is not the same thing as describing the loaf characters by a system of bakers' marks, as is the general practice in America and of some English workers. Bakers' marks depend on personal judgments of such elusive characters as crumb colour and bloom, grain, texture and spring, dough body and stability. What is needed are precise physical methods of *measuring* these characters—methods of measurement that are independent of any personal equatoin.

How far we are from even approximate standardisation of test baking technique can be realised only by those who have experience of this kind of work. At present we are in the position of having to use a complicated but indispensable test which is, scientifically speaking, of the crudest possible character in the hope of obtaining results which are sufficiently quantitative to be arranged in some kind of order.

The work done in the writers' laboratories and bakehouse during the past twelve years towards standardising test baking technique—considerable in the aggregate, but little enough when viewed in relation to the whole problem—will be described in this series of papers.

All doughs are fermented in a proving cabinet in cubical, lidless,

teak boxes of 6-inch sides. The final proving in the baking tins also takes place in the cabinet in the case of tinned loaves. Normally, all doughs are made at a temperature of 80° F.

Cob doughs are fermented in the usual way in the cabinet, but after moulding into spherical balls are allowed to prove side by side on a tray (made to fit the oven), the doughs being covered with a damp cloth. The whole tray is then transferred to the oven.

The ovens are standard Artofex models, of internal dimensions 3 ft. × 3 ft., each capable of taking 32 2-lb. tins. The heating is electrical and the heaters both above and below are embedded in a special cement of which both roof and sole are made. This ensures a good reserve of heat—"solid heat," to use the bakers' expressive phrase. With a full load of replicate loaves the front row of 4 usually have paler crusts and poorer oven-spring than the remainder of the batch. This indicates a lower temperature at the mouth of the oven, but the temperature is satisfactorily uniform in all other parts of the oven as shown by the close similarity of crust colour and bloom and oven-spring of all replicate loaves of a full load, except those of the front row.

Relation between Amount of Yeast and Period of Fermentation

It is well known that if a dough batch of any given flour is made up, say, at 80° F. and with 1% of yeast, and loaves are baked at hourly intervals from one up to 10 or 12 hours, the earliest loaves will be small and stodgy owing to under-fermentation. Successive loaves will increase in volume and will improve in all crumb characters up to a maximum; that is, crumb will become softer and of better spring, grain more open, texture silkier, and colour and bloom paler and brighter. The later loaves will decrease in volume and deteriorate in all crumb characters until they become obviously sour through over-fermentation. There will be one particular loaf better in all characters than any of the others; that is, there will be one best loaf. With a long fermentation flour of considerable fermentation tolerance, such as No. 1 or No. 2 N. Manitoba, the best loaf may be thrown at 6 or 7 hours from dough making, and there may be one or more loaves on either side of the best only slightly inferior to the best. That is, there will be a considerable period of time over which satisfactory bread may be made. This is, in fact, what is meant by fermentation tolerance: with such a flour, under certain fermentation conditions, an hour or so, more or less, will have but little effect on the quality of the bread produced. Another flour, say, an all-English, or short fermentation flour, will throw its best loaf, under similar fermentation conditions, much earlier and the loaves immediately preceding and following the

best may be markedly inferior to the best. In this case fermentation tolerance is poor and there is only a very short period of time during which good bread may be made. With such a flour, any marked deviation in fermentation time, dough temperature, or amount of yeast will have a marked effect on the quality of the bread produced.

With any flour, all other conditions, such as dough temperature, absorption, amount of salt, *etc.*, being maintained constant, the greater the percentage of yeast the shorter will be the time required for the best loaf to be thrown, and the smaller the percentage of yeast the longer will be the optimum fermentation time. Yeast and time of fermentation vary inversely, but not in arithmetical proportion. For commercial dough batches, Kirkland and Dorée [3] give the relation between yeast and time shown in Table I and Figure 1, Curve *A*, for a

TABLE I

RELATION BETWEEN PERCENTAGE OF YEAST AND TIME OF FERMENTATION (KIRKLAND AND DORÉE)

Time in trough, *i.e.*, excluding proving time,	Yeast per sack	Yeast, %
hours		
10	10 oz.	0.223
9	12 oz.	0.268
8	14 oz.	0.312
7	1 lb.	0.357
6	1 lb. 2 oz.	0.402
5	1 lb. 4 oz.	0.446
4	1½–1¾ lb.	0.580
3	1¾–2 lb.	0.670
2	3 lb.	1.071
1	4½ lb.	1.607

reasonably "strong" blend. It will be seen from Figure 1, Curve *A*, that there is no simple arithmetical relationship between yeast and time. If, however, we plot the logarithms of the yeast percentages against the logarithms of the time of fermentation, all the points of Kirkland's table, except the first and the last, lie on a straight line as in Figure 1, Curve *B*. To bring the first (10 hours) and last (1 hour) points on the straight line, the amount of yeast required would be 11¼ oz. (= 0.25%) and 5½ lb. (= 1.90%), respectively, instead of the 10 oz. and 4½ lb. stated by Kirkland and Dorée. It is, however, not easy in practice to determine precisely the correct amounts of yeast for very long or for very short fermentations, and Kirkland's figures, which are generally accepted, certainly indicate that the relation between yeast percentage and time of fermentation is a logarithmic one.

[3] Kirkland, J., and Dorée, C. Reports on Research. National Bakery School, London (1924).

To test this relationship further, several series of baking tests were carried out with a number of flours. Two only of the series need be referred to in any detail, as all yielded similar results. Apparently,

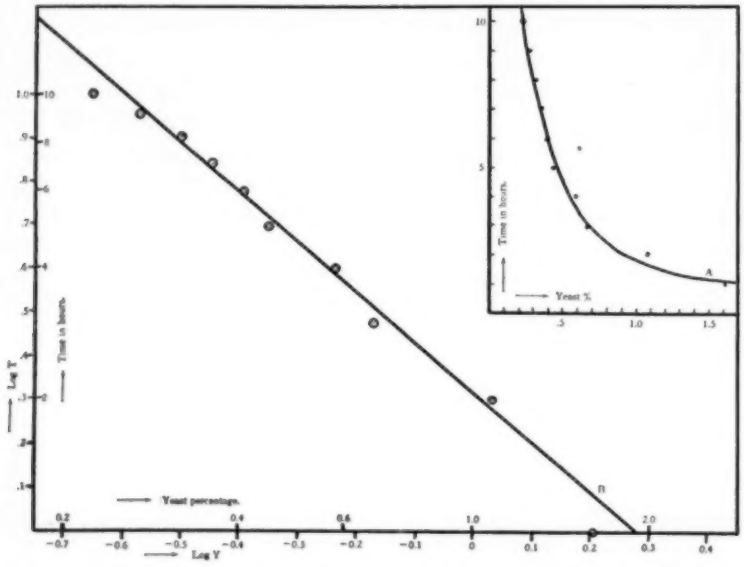

Figure 1. Relation between yeast percentage and time of fermentation of best loaf (based on Kirkland's data). *A*. Yeast percentages plotted against times of fermentation. *B*. Logarithms of yeast percentages plotted against logarithms of times of fermentation.

the relation between percentage of yeast and time of fermentation (all other factors being constant) is a logarithmic one;

$$\log y_1 - \log y_2 = k\,(\log t_2 - \log t_1), \qquad \text{or}$$
$$\frac{\log y_1 - \log y_2}{\log t_2 - \log t_1} = k,$$

in which y_1 and y_2 are percentages of yeast, t_1 and t_2 the corresponding times of fermentation (including proof) for the best loaves obtainable, and k = a constant the value of which should depend on the type of flour. For the short patent flour and yeast used in this experiment, $k = 1.35$.

One series of tests was carried out with a "basic grade" London flour. The yeast percentages and times of fermentation (including final proof) were as follows:

3% yeast, period of fermentation $1\frac{3}{4}$ to $4\frac{3}{4}$ hr., punched at $\frac{3}{4}$-hr. intervals

2% yeast, period of fermentation $1\frac{3}{4}$ to $4\frac{3}{4}$ hr., punched at $\frac{3}{4}$-hr. intervals

1% yeast, period of fermentation $3\frac{1}{4}$ to $6\frac{1}{4}$ hr., punched at $\frac{3}{4}$-hr. intervals

0.75% yeast, period of fermentation $5\frac{1}{2}$ to $9\frac{1}{4}$ hr., punched at $\frac{3}{4}$-hr. intervals

0.5% yeast, period of fermentation $7\frac{3}{4}$ to 10 hr., punched at $\frac{3}{4}$-hr. intervals

0.25% yeast, period of fermentation 11 to 17 hr., punched at 2-hr. intervals

The same absorption (16 gal. per sack) and percentage of salt (1.25%) were used in all doughs, and tinned loaves were made. The 3% and 2% loaves were baked together at one time; the 1% and 0.75% loaves were baked together; and the 0.5% and 0.25% loaves were baked together. The best loaves were thrown at the following times:

With 3% yeast at $3\frac{1}{4}$ hr.
With 2% yeast at 4 hr.
With 1% yeast at $6\frac{1}{4}$ hr.
With 0.75% yeast at $7\frac{3}{4}$ hr. (7-hr. loaf very similar)
With 0.5% yeast at $8\frac{1}{2}$ hr. ($9\frac{1}{4}$-hr. loaf very similar)
With 0.25% yeast at 11 hr. (poor loaf)

The logarithms of the yeast percentages are plotted against those of the fermentation times in Figure 2, Curve *A*. The 3%–$3\frac{1}{4}$ hr., 2%–4 hr., 1%–$6\frac{1}{4}$ hr., and 0.75%–$7\frac{3}{4}$ hr. points lie on a straight line as

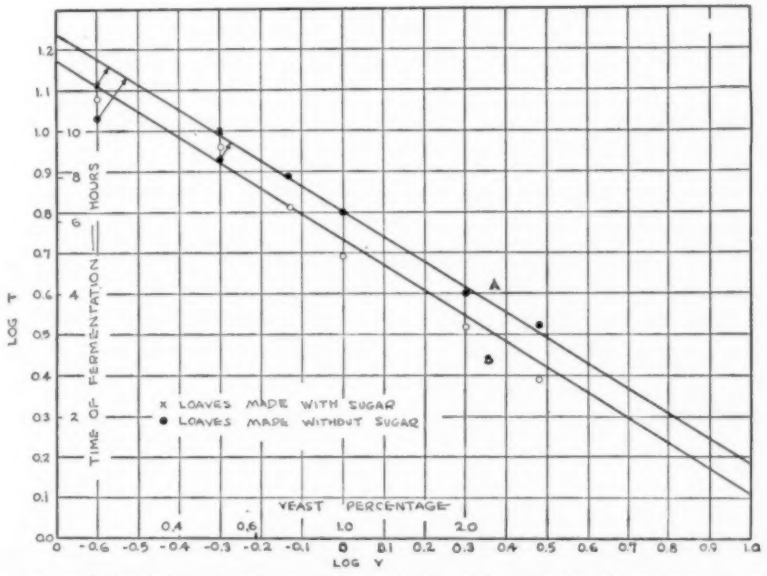

Figure 2. Relation between yeast percentage and time of fermentation of best loaf. *A*. "Basic grade" flour. *B*. Short patent flour.

expected. The 0.5%–8½ hr. and 0.25%–11 hr. points lie badly off the straight line. It was suspected, and confirmed from the gas figures given in Table II*A* and II*B*, that the two latter deviations were due

TABLE II*A*

GAS PRODUCTION AT HOURLY INTERVALS UP TO 24 HOURS OF A SAMPLE OF FLOUR WITH DIFFERENT AMOUNTS OF YEAST

Yeast percentage	Gas production					
	3%	2%	1%	0.75%	0.5%	0.25%
Time	*cc.*	*cc.*	*cc.*	*cc.*	*cc.*	*cc.*
1st hour	60	40	15	10	9	10
2nd hour	110	71	37	29	16	5
3rd hour	121	98	57	43	28	11
4th hour	86	107	66	53	38	19
5th hour	46	80	79	70	49	24
6th hour	36	45	88	77	60	31
7th hour	31	33	68	77	70	45
8th hour	25	29	44	68	76	52
9th hour	25	25	33	38	64	53
10th hour	22	23	25	27	44	65
11th hour	19	21	25	24	36	65
12th hour	19	20	23	25	29	53
13th hour	19	20	22	24	28	42
14th hour	18	20	20	22	23	36
15th hour	17	18	19	20	24	31
16th hour	18	14	19	16	28	27
17th hour	18	14	20	25	27	23
18th hour	13	15	17	16	15	20
19th hour	15	17	15	17	19	18
20th hour	13	11	15	14	17	16
21st hour	13	14	14	15	15	17
22nd hour	15	13	14	14	18	17
23rd hour	12	12	15	15	19	18
24th hour	15	13	16	14	15	15
Total for 24 hours	786	783	766	753	757	713

to inadequate gas production during final proof. The 0.5% and 0.25% series were therefore re-baked, the 0.5% series with the addition of 2% of cane sugar and the 0.25% series in duplicate, one set containing 2% cane sugar and the other 0.1% malt extract and 0.05% ammonium phosphate and no cane sugar. The cane sugar (but not the malt extract) stimulated gas production (see Table II, *B*) during final proof and the best loaves were now thrown at 10 hr. (with 0.5% yeast) instead of at 8½ hr., and at 13 hr. (with 0.25% yeast) instead of 11 hr. As will be seen from Figure 2, Curve *A*, the 0.5%–10 hr. point is now on the straight log y − log t curve, and the 0.25%–11 hr. point nearer to it than before.[4] The reason why the 0.25% point appears always

[4] It will be noticed from Table II*B*, that with very small amounts of yeast, *e.g.*, 0.5% or less, and very long fermentations, *e.g.*, 10 or more hours, malt extract and ammonium phosphate do not increase gas production during final proof. Cane sugar, on the other hand, does. It follows that in such cases, and in commercial bakery practice when overnight doughs are made, added sugar is a better aid to gas production than is malt extract.

to be off the curve is probably the difficulty of obtaining adequate gas production during final proof after such a long period. The value of k for this flour was 1.50.

TABLE II*B*

GAS PRODUCTION AT HOURLY INTERVALS UP TO 24 HOURS WITH AND WITHOUT 2% CANE SUGAR, OR 0.1% MALT EXTRACT AND 0.05% AMMONIUM PHOSPHATE

Time	Gas production					
	0.25% yeast	0.5% yeast + sugar	0.5% yeast + malt	0.25% yeast	0.25% yeast + sugar	0.25% yeast + malt
	cc.	*cc.*	*cc.*	*cc.*	*cc.*	*cc.*
1st hour	9	13	8	10	10	12
2nd hour	16	14	14	5	8	8
3rd hour	28	31	28	11	12	12
4th hour	38	42	41	19	20	18
5th hour	49	52	56	24	30	30
6th hour	60	64	64	31	36	38
7th hour	70	73	79	45	51	49
8th hour	76	76	90	52	63	64
9th hour	64	89	73	53	58	74
10th hour	44	80	37	65	80	80
11th hour	36	72	30	65	79	62
12th hour	29	64	32	53	73	44
13th hour	28	44	25	42	69	34
14th hour	23	33	24	36	60	35
15th hour	24	28	26	31	51	30
16th hour	28	29	25	27	42	37
17th hour	27	26	28	23	34	30
18th hour	15	20	18	20	28	23
19th hour	19	19	17	18	23	20
20th hour	17	19	17	16	18	20
21st hour	15	15	18	17	20	18
22nd hour	18	17	15	17	19	15
23rd hour	19	18	15	18	19	18
24th hour	15	14	17	15	20	18
Total for 24 hours	757	952	797	713	923	789

It will be noticed from Table IV that in each series of loaves made with fixed amount of yeast, and varying only in fermentation times, the best loaf is also the biggest. Also (from Table III) that the best loaves of the 3%, 2%, 1%, and 0.75% series were of substantially similar volume. They were also very closely similar in all crust and crumb characters, including colour and bloom of crust and crumb, grain, texture and softness of crumb. They were, in fact, essentially replicate loaves, and excellent replicates. On the other hand, the best of the 0.50% loaves was slightly inferior to the best loaves of the higher yeast series in grain and in crumb colour and bloom, while the best of the 0.25% series was markedly inferior in volume and in crust and crumb characters and especially in crumb colour and grain.

Now, while with the above flour it was possible to obtain equally good bread when using anything from 3% to 0.75% yeast with appropriate alterations in fermentation times, it has been found that

TABLE III

DETAILS OF THE BEST LOAVES MADE FROM "BASIC GRADE" FLOUR WITH DIFFERENT AMOUNTS OF YEAST

(Tinned loaves were made and loaf volumes are expressed as areas of vertical cross-section of the loaves in square inches)

Yeast, %	Time to best loaf	Area of cross-section of loaf	Loaf pH
	hours	*sq. in.*	
3	3.25	31.5	5.74
2	4.00	32.4	5.76
1	6.25	32.0	5.69
0.75	7.75	31.6	5.62
0.50 [1]	10.00	32.4	5.60
0.25 [1]	13.00	30.8	5.29
0.50 [2]	8.50	30.0	5.62
0.25 [2]	11.00	27.4	5.49
0.25 [3]	11.00	28.8	5.35

[1] Plus 2% cane sugar.
[2] No cane sugar nor malt extract.
[3] Plus 0.1% malt extract and 0.05% ammonium phosphate.

with stronger flours it is possible to obtain bread made with 0.50% yeast which is also equal to the best made with the larger amounts, while on the other hand it is only possible to obtain the best bread from weak flours when using a relatively larger amount of yeast and short fermentation time.

The reason for this is that as the dough ages it deteriorates irrespective of its yeast content, this deterioration being more rapid the weaker the flour.[5] When the rate of deterioration is slow, as in strong flours, it is possible to obtain equally good bread when using either a large amount of yeast and a short fermentation time, or a small amount of yeast and an appropriately longer fermentation time. On the other hand, the rapid deterioration with weaker flours only makes it possible to obtain good bread (*i.e.*, good for that particular flour) by reducing the time of fermentation and using large amounts of yeast. This has a bearing on commercial baking practice: although satisfactory bread can be made from overnight doughs, the best bread produced under such circumstances will not be as good as that obtained from the same flour with a comparatively short fermentation and a larger amount of yeast. This point is also illustrated by Figure 3, in which the inferiority of the loaves made with 0.5% and 0.25% yeast are seen.

[5] This deterioration is associated with a fall, which is progressive with aging of dough, in dough viscosity and elasticity modulus. See paper: "A Study of Some Physical Properties of Flour Doughs in Relation to their Breadmaking Qualities," by P. Halton and G. W. Scott Blair. Cereal Chem. 14: 201–218 (1937).

TABLE IV

AREAS OF CROSS-SECTION AND pH's OF LOAVES MADE FROM "BASIC GRADE" FLOUR WITH VARYING PERCENTAGES OF YEAST AND FERMENTATION PERIODS

Yeast, %	Fermentation	Area of cross-section	Loaf pH
	hours	*sq. in.*	
3	1.75	26.3	5.78
	2.50	27.5	5.76
	3.25	31.5	5.74
	4.00	25.6	5.71
	4.75	25.2	5.66
2	1.75	25.7	5.84
	2.50	26.9	5.80
	3.25	29.0	5.78
	4.00	32.4	5.76
	4.75	28.8	5.73
1	3.25	24.1	5.77
	4.00	26.6	5.74
	4.75	29.2	5.74
	5.50	28.4	5.72
	6.25	32.0	5.69
0.75	5.50	28.5	5.74
	6.25	30.6	5.74
	7.00	30.7	5.65
	7.75	31.6	5.62
	8.50	27.2	5.64
	9.25	23.8	5.61
0.50 [1]	8.50	30.0	5.70
	9.25	31.6	5.62
	10.00	32.4	5.60
	10.75	31.6	5.51
0.25 [1]	11.00	29.0	5.59
	13.00	30.8	5.29
	15.00	26.5	5.03
	17.00	25.2	4.91
0.50 [2]	7.75	27.6	5.72
	8.50	20.0	5.62
	9.25	29.4	5.61
	10.00	24.3	5.53
0.25 [2]	11.00	27.4	5.49
	13.00	26.8	5.14
	15.00	22.5	4.86
	17.00	21.2	4.69
0.25 [3]	11.00	28.8	5.35
	13.00	26.9	5.10
	15.00	25.2	4.87
	17.00	23.3	4.61

[1] Plus 2% cane sugar.
[2] No cane sugar nor malt extract.
[3] Plus 0.1% malt extract and 0.05% ammonium phosphate.

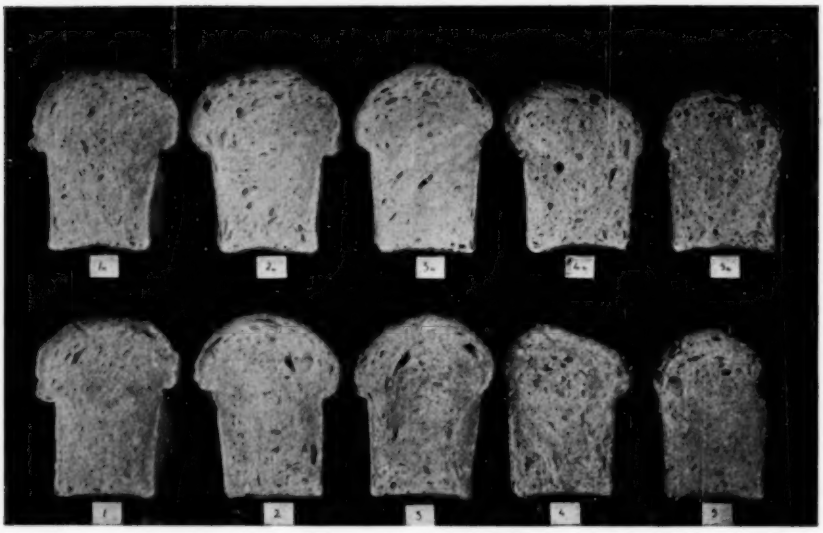

Figure 3. Loaves from left to right. 1. 2% yeast with 4 hr. fermentation. 2. 1% yeast with 5½ hr. fermentation. 3. 0.75% yeast with 7¾ hr. fermentation. 4. 0.5% yeast with 9¼ hr. fermentation. 5. 0.25% yeast with 13¾ hr. fermentation. Loaves on top row had ¾ hr. proof, those on second row 1 hr. proof. Note inferiority of loaves 4 and 5.

A further series of trials was carried out with a short patent flour from the same grist as the basic grade. The same amount of yeast was used and 2% of cane sugar was added to all loaves containing less than 1% of yeast. The best loaves were thrown at the following times:

With 3% yeast at 2½ hr.
With 2% yeast at 3¼ hr.
With 1% yeast at 4¾ hr. (4 and 5½-hr. loaves good)
With 0.75% yeast at 6¼ hr. (5½-hr. loaf closely similar)
With 0.5% yeast at 9¼ hr. (8½ to 10¾-hr. loaves all good)
With 0.25% yeast at 12 hr. (11 and 13-hr. loaves closely similar)

The logarithms of the yeast percentages plotted against the logarithms of the fermentation times give the straight line *B* of Figure 2. The two lines, *A* for the basic grade and *B* for the short patent, are practically parallel, the slopes (log *y*/log *t*) being 1.50 and 1.46 respectively. Curve *B*, however, lies below Curve *A*, indicating that at all yeast percentages the patent flour threw its best loaves earlier than the corresponding "straight run" flour.

Relation between Amount of Yeast and Temperature of Fermentation

Saunders,[6] in Canada, studied the effect of varying yeast content on time of fermentation for four different flours—a first patent, a

[6] Saunders, C. E. Researches in regard to wheat, flour and bread. Can. Dept. Agr. Bull. 97 (1921).

special patent, a winter wheat flour, and a durum wheat flour. He varied the yeast content from 0.8% to 7.2%, and employed two different dough temperatures, *viz.*, 31° C. (= 87.8° F.) and 26.6° C. (= 79.9° F.). In the case of the winter wheat flour the logarithms of the yeast percentages are plotted against the logarithms of the fermentation times in Figure 4; the points fall approximately on two

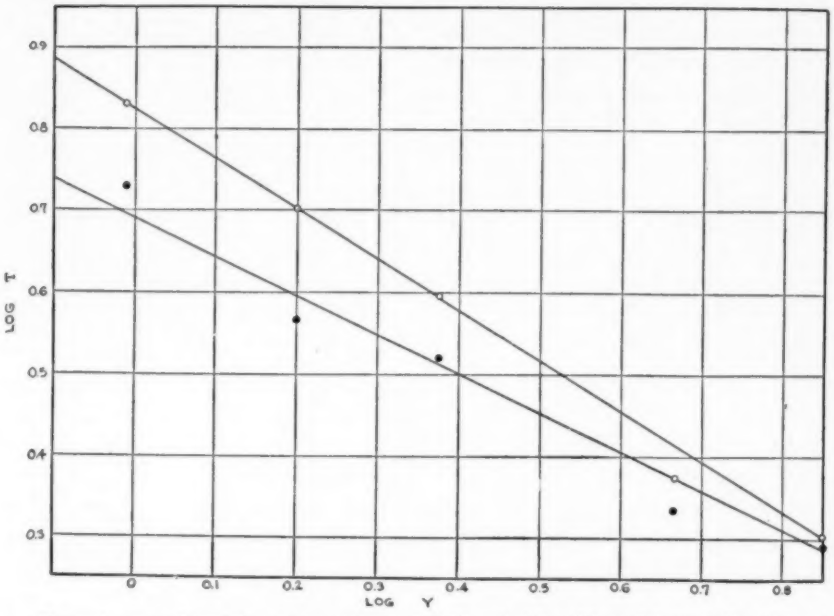

Figure 4. Logarithms of yeast percentages plotted against logarithms of fermentation times at two different temperatures (based on Saunders' data). Note that 8% yeast (log $y = 0.9$) time of fermentation is independent of the temperature as indicated by the two curves intersecting.

straight lines which converge to a point corresponding approximately to log $y = 0.9$, equivalent to a yeast percentage of 8. This convergence of the log y − log t curves for different temperatures to a point corresponding to 8% yeast occurred with all four flours baked by Saunders as is indicated by the following figures:

Flour	Fermentation time with 0.8% yeast						Fermentation time with 7.2% yeast					
	At 87.8° F.		At 79.9° F.		Difference		At 87.8° F.		At 79.9° F.		Difference	
	hr.	*min.*	*hr.*	*min.*	*hr.*	*min.*	*hr.*	*min.*	*hr.*	*min.*	*hr.*	*min.*
First patent	5	13	6	42	1	29	1	56	2	0	−	4
Special patent	5	9	6	24	1	15	1	51	1	52	−	1
Winter wheat	5	22	6	56	1	34	1	48	1	50	−	2
Durum wheat	5	11	6	49	1	38	2	10	2	23	−	13

This convergence suggests that the effect of increasing dough temperature in reducing time of fermentation is less the greater the percentage of yeast, and that with 8% yeast the time required for correct fermentation is independent of the temperature. In other words, with 8% yeast and a single fixed fermentation time precisely similar bread should result over a wide range of dough temperature. To test this point five loaves were made from a straight run flour. One, as control, was made according to the formula: 2% yeast, dough temperature 80° F., and fermentation time 3¼ hr. to oven. The other four were made up with 8% yeast, fermentation time of 1 hr-20 min. to oven, and dough temperature of 65°, 75°, 85°, and 95° F. respectively. All were given the same absorption (15 gal. per sack) and salt (1¼%). Proving times were varied (according to dough temperature) so as to ensure a similar rise for each dough during proof. The doughs handled very differently: the 65° dough was tough and clay-like; the doughs decreased in toughness and increased in tenderness and extensibility with increasing dough temperature, the 95° dough being very tender and extensible. The loaves, however, with one exception, were closely similar in all characters. The 65° loaf was slightly the smallest, of poor crumb colour and bloom, open honeycomb grain and coarse texture. The other three loaves (made from the 75°, 85° and 95° doughs) and the control were closely similar in volume, outside appearances, in softness and spring of crumb, and in grain. The control was slightly the best in crumb colour and bloom, the 85° loaf came next, then the 75° loaf, the 95° loaf being the poorest of the four in colour. The differences, however, were really slight and the loaves were substantially replicates.

The hydrogen ion concentrations of the loaf crumbs were substantially identical, indicating that fermentation had proceeded to the same extent in all; *i.e.*, the doughs were all equally ripe when baked. The relevant data are given in Table V.

TABLE V

LOAF VOLUMES AND pH OF LOAVES BAKED AT DIFFERENT TEMPERATURES WITH 8% YEAST

Yeast, %	Fermentation time	Dough temperature	Loaf volume	pH of crumb
		° *F.*	*cc.*	
2	3 hr. 15 min.	80	2815	5.66
8	1 hr. 20 min.	65	2712	5.71
8	1 hr. 20 min.	75	2849	5.70
8	1 hr. 20 min.	85	2772	5.65
8	1 hr. 20 min.	95	2810	5.64

Relation of Size of Dough to Rate of Fermentation

It is well known that higher yeast percentages are necessary for small experimental doughs than for large commercial batches. Thus, Kirkland recommends 0.58% and 0.67% yeast for 3- and 4-hr. doughs in the case of batches of one sack or more, but for small batches made from 5 lb. of flour he recommends at least 1.25% of yeast for a 3-hr. dough. The writers have found that for most London flours 2% yeast gives best results with 3- to 4-hr. doughs made from 28 oz. of flour. In other words, the smaller the dough the slower the fermentation, other factors remaining the same. This is usually attributed to the more rapid loss of heat from small doughs under ordinary bakehouse conditions, the result being in effect a lower fermentation temperature.

In test baking, with satisfactory control of dough temperature and very much smaller batches than is the case in commercial bakeries, the influence of size of dough on rate of fermentation should be less marked. It is, however, appreciable; it varies with different flours and in some cases may be quite marked.

To avoid difficulties due to varying size of dough batch, it is the writers' practice, when it is necessary to bake loaves at intervals from the same dough, to make not one dough batch sufficient to yield n loaves, but n separate single loaf doughs which can be baked after the appropriate fermentation times. Further, instead of making the single loaf doughs at one time, and baking them at $\frac{3}{4}$-hr. intervals, the doughs are made at $\frac{3}{4}$-hr. intervals and are sent to the oven together. In this way errors due to varying size of batch and varying oven temperature are reduced to a minimum.

Test Baking Technique

In view of the considerations already discussed and as a result of several years' experience in examining a great variety of flours, the writers have come to the conclusion that it is not practicable to devise a single system of test baking that will meet all requirements. The system must be varied in accordance with the kind of information one wishes to obtain. There are two main fields of activity in which test baking is an essential technique—mill control and flour research. The objects are different in the two activities and a baking technique entirely adequate in one may be quite unsuitable or even valueless in the other.

Test Baking in Mill Control: the Single Test Bake

In mill control the miller is interested less in the intrinsic character of his flour than in its regularity of quality. If he is still in business in this highly competitive industry, that fact alone means that he is

producing a flour which normally gives satisfaction to his customers. His main immediate object is, while taking full advantage of price differences between the various wheats available, to maintain the quality of his flour at a constant level. To test this regularity, series of single baking tests—either alone or in duplicate—are adequate, in addition, of course, to more scientific tests, such as determination of gas production, maltose figures, *etc.*

In test baking of this type a rigid technique should be adopted, the only variable allowable being water absorption of dough. Using a fixed, predetermined, absorption an experienced baker can tell from the handling of a dough whether the given absorption is correct, insufficient or too great. But it is desirable to use the correct absorptions because, by so doing, all doughs are brought into comparable states. They bake better in consequence, and correct judgments of dough and loaf quality should result. For example, it may happen one week that a miller's flour is of unduly high absorption—due, possibly, to the use of certain deliveries of Nos. 5 and 6 Manitobas, which sometimes produce this effect—but unchanged in other characters. If the correct, increased absorption is given, both dough and loaf will be normal. If the usual fixed absorption is given, the baker will certainly notice the difference in absorption, but the dough being too dry will neither handle nor "work" satisfactorily, and the resulting loaf will be abnormal. Such a flour might be condemned by the test baker—as it would be probably by the customer who is using a fixed technique.

It is not necessary in this kind of test baking to produce the best loaf. The object is not to test a flour's capacity to produce an excellent loaf, but rather to test its response to a fixed baking technique. Nevertheless, the writers find it helpful to employ a very full fermentation. If a flour is tested with a rigid technique, involving a maximum fermentation and maximum proof, variations in quality will show up very clearly. If the dough is more tender than usual, the dough at proof and the loaf will show obvious signs of over-fermentation; if the flour is unduly "strong," the dough and loaf will be "green" or underfermented. The writers use 2% of yeast, $1\frac{1}{4}$% of salt, dough temperature of 80° F., and a fermentation time, including final proof, of $3\frac{1}{4}$ hr.

It need hardly be added that no condiment—neither improver nor yeast stimulant—should be used in this type of test baking. If a flour is defective in gas production, that is one of the things it is desirable to discover and which would certainly be overlooked if any "help"—such as malt extract and ammonium phosphate—were given the flour.

Test Baking in Flour Research: the Multiple Differential System of Test Baking

In flour research the object of test baking is entirely different. We are not now testing a flour's regularity. We are seeking detailed information concerning dough and loaf characters of an unknown flour. Is it a long or short fermentation flour? What is its fermentation tolerance? How are these characters modified by blending with "stronger" or "weaker" flours? What is the flour's response to improvers? And so on. It seems to the writers that a single test bake is of little value here. It is true that an experienced baker can obtain useful information on a series of flours by means of a single test bake on each. One dough has better body and stability than another. One is obviously over-fermented, while another would "stand up" to much more drastic treatment, and so on. Such information is, however, not sufficiently precise or extensive for all purposes. Moreover, we are largely dependent on the baker's opinions for grouping the flours under consideration. We are, in effect, classifying not the flours but a baker's opinions of the flours. The opinions of an experienced baker may be worthy of close study and classification, but that is another problem with which we are not at the moment concerned.

What is needed is a system of test baking that will enable a scientific worker to appreciate clearly and plainly the niceties of flour quality without his being entirely dependent on the baker's opinion. In such a system the baker is hardly more than an instrument in manipulating dough and making bread. His opinion is sought and valued by the scientific worker mainly as corroboration of opinions already formed as a result of the bake.

This point of view seems to be the basis of the system of test baking devised for the Home Grown Wheat Committee of the National Association of British and Irish Millers by A. E. Humphries, one of the very few workers who have appreciated the full implications of test baking. His system, indeed, is the foundation on which the writers have built their own, more elaborate system to be described later. This type of system may be called, for want of a better name, the *multiple differential* system of test baking—*multiple* because several simultaneous bakes are involved of progressively increasing severity, *differential* because an attempt is made to assess the magnitude of the flour's response to equal increments of severity of fermentation.

Humphries' tests were devised originally for use in his work on English wheat trials—hence his notation ET1, ET2, *etc.*, in enumerating the tests. The tests are as follows:

ET1	1.25% yeast, 3 hours' fermentation (including final proof) at 80° F.
ET2	1% yeast, 4 hours' fermentation (including final proof) at 80° F.
ET3	0.75% yeast, 6 hours' fermentation (including final proof) at 80° F.
ET4	0.5% yeast, 8 hours' fermentation (including final proof) at 80° F.
ET5	0.5% yeast, 8 hours' fermentation (including final proof) at 85° F.

The fermentations involved are of increasing severity from ET1 to ET5, the increases in time of fermentation being more than sufficient to compensate for the decreasing yeast percentages between ET1 and ET4. Flours from ordinary English wheats would behave best with ET1, Yeoman flour with ET2 or ET3. Most commercial flours in the London area should stand up satisfactorily to ET4, while very few commercial flours would behave well to ET5. The system is excellent for differentiating flours into groups—for separating the sheep from the goats. In much of their work the writers have felt the need of a closer differentiation of flours than is possible with this system and have elaborated the process to suit their requirements.

It has already been shown that, within limits, yeast, time, and temperature are interchangeable factors in fermentation. The writers prefer, therefore, to use a constant temperature (80° F.) and a constant yeast percentage (2% or, in some cases, 1%), while increasing the times of fermentation by constant and rather small increments (usually ¾-hr. intervals). Incidentally, this reduces the fermentation variables from three to one. In any set of loaves baked on this system the fermentation intervals between adjacent loaves are always the same. Such a system enables one to obtain clear and precise information concerning:

(*a*) the intrinsic characters of dough and loaf,
(*b*) the length of fermentation for the best loaf to be thrown,
(*c*) the fermentation tolerance,
(*d*) the response of any or all dough or loaf characters to additional variables, such as addition of improver or blending with varying proportions of other flours.

It is necessary to ensure adequate gas production at all stages of fermentation. This is done by adding to the flour, when necessary, 0.1% of highly diastatic malt extract and 0.05% of ammonium phosphate, or 2% of cane sugar.

The value of this system of test baking can perhaps best be appreciated from a consideration of the results obtained from an extended examination of a No. 1 N. Manitoba flour, an ordinary English non-Yeoman flour, and blends of these containing from 10% to 90% of English flour. Eleven sets of tinned loaves were made corresponding to the nine blends, the all-English and the all-Manitoba flours—62 loaves in all. One per cent of yeast and a fermentation temperature of 80° F. were employed. All doughs were made at ¾-hr. intervals. The results may be summarized as follows:

Blend	Fermentation periods	Best loaf thrown at	Good [1] loaves thrown at
	hours	*hours*	*hours*
Manitoba alone	4¾ to 9¼	7¾	5½ to 7¾
90% Manitoba + 10% English	5½ to 9¼	7 and 7¾	6¼ to 8½
80% Manitoba + 20% English	5½ to 9¼	7 and 7¾	6¼ to 8½
70% Manitoba + 30% English	5½ to 9¼	7	6¼ to 7¾
60% Manitoba + 40% English	4¾ to 7¾	7	6¼ to 7¾
50% Manitoba + 50% English	4¾ to 7¾	7	6¼ to 7
40% Manitoba + 60% English	4¾ to 7¾	7	6¼ to 7
30% Manitoba + 70% English	4 to 7	6¼	6¼
20% Manitoba + 80% English	4 to 7	5½	5½
10% Manitoba + 90% English	3¼ to 7	5½	5½
English alone	2½ to 6¾	4¾	4¾

[1] By "good" loaves is meant loaves only slightly inferior to the best loaf in each series. The best all-English loaf was not really a good loaf.

The results are shown diagrammatically in Figure 5.

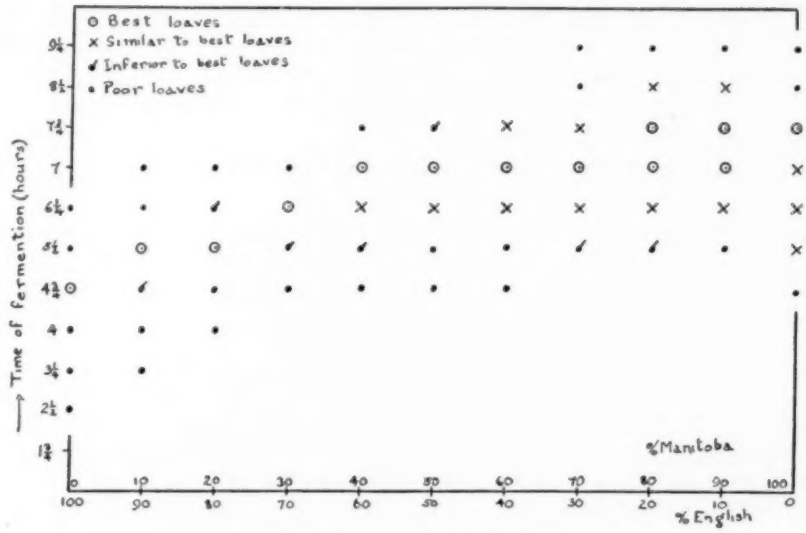

Figure 5. Baking quality of Manitoba-English blends.

The all-Manitoba loaves were, of course, incomparably better than the all-English loaves, and loaf quality improved progressively in the blends with increasing content of Manitoba flour. This generalisation is too well known to need any emphasis. A close study of Figure 5 shows clearly the following interesting points which, however, were brought out far more clearly by the loaves themselves when laid out in order on the laboratory bench.

1. The best Manitoba loaf was thrown at 7¾ hr. and the best English at 4¾ hr. Manitoba is a long fermentation flour, English a short fermentation flour.

2. There is only one best English loaf, the loaves immediately preceding and following the best being markedly inferior to the best. There are three other loaves closely similar to the best all-Manitoba loaf. The fermentation tolerance or spread of the Manitoba flour greatly exceeds that of the English. That is, bread closely similar to the best Manitoba was made over a period of $2\frac{1}{4}$ hr., whereas the best English was confined to a period of, say $\frac{1}{2}$ hr.

3. With increasing content of Manitoba, the time at which the best loaf was thrown increased rather rapidly from $4\frac{3}{4}$ hr. (all-English) to 7 hr. (40% blend), after which it increased very slowly to $7\frac{3}{4}$ hr. (all-Manitoba).

4. The fermentation tolerance or spread increased with increasing content of Manitoba, slowly at first, then more rapidly. Up to 30% Manitoba only one best loaf was thrown, the difference between the best and the next best loaves diminishing with increasing Manitoba content. The 40% and 50% blends threw two good loaves each, the 60% and 70% three each, and the 80%, 90%, and 100% Manitoba flours four good loaves each.

5. Not all loaf (and dough) characters vary at the same rate with increasing Manitoba content. *E.g.*, length of fermentation increased rapidly at first, then more slowly; fermentation tolerance increased slowly at first, then more rapidly.

6. With increasing English content, not only does the best loaf become intrinsically poorer but it is thrown earlier. This twofold effect of "weakness" is not as widely appreciated as its importance would indicate although it is an important consideration in wheat blending. Of two "weak" wheats, of similar price and character (*i.e.*, intrinsic loaf character), the better and more useful of the two is the one with the longer fermentation period. This consideration may be important in the use of such wheats as ordinary English, French, German, Polish, certain types of Danubian, White Pacifics, *etc.*

To make this investigation of these two flours more complete, the flours making the eleven best loaves were re-baked as tinned loaves and as cobs. The appropriate fermentation times were employed and all loaves were sent to the oven together. The tinned loaves could be divided into two groups, the first consisting of excellent to moderately good loaves made from the blends containing 100% to 40% Manitoba, the other consisting of poor loaves containing less than 40% Manitoba. As the percentage of Manitoba flour decreased from 100% to 40% the loaves showed progressive falling off in colour and softness of crumb, the grain becoming closer and more typically English and the texture coarser. The deterioration was approximately constant for each 10% decrease in Manitoba content. Below 40% Manitoba there was a more

rapid falling off in all loaf characters, the all-English loaf being small, of deep cream, almost yellow, colour; with tough, harsh crumb; open, irregular, honeycomb grain, and very coarse texture. The series of cob loaves showed similar differences to the tinned loaves; in addition, it was possible to follow the changes in dough characters. Dough body and stability diminished with decreasing Manitoba content, comparatively slowly at first, then more rapidly when less than 40% Manitoba was present.

The net deterioration in dough and loaf characters in these two sets of best loaves of Manitoba-English blends is indicated diagrammatically in Figure 6.

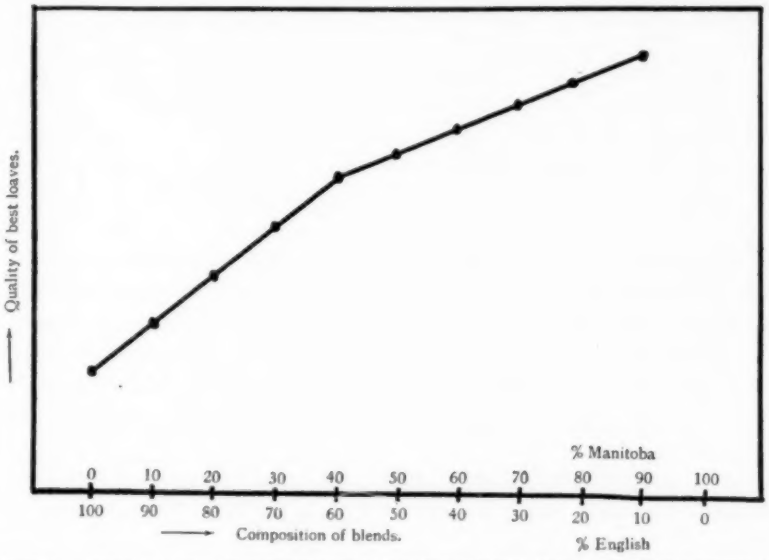

Figure 6. Variation in quality of best loaves of Manitoba-English blends (purely diagrammatic).

These results lend support to a generalisation widely held by bakers that, in blending flours, "a weak flour will pull a strong one down to a greater degree than the strong flour will pull the weak one up." Referring to Figure 6, if we regard the 40% Manitoba-60% English blend as the poorest flour that would give satisfaction commercially, then it is evident that the deterioration in this blend produced by the further addition of 20% English is greater in magnitude than the improvement that would result from the incorporation of 20% of Manitoba. The generalisation does not hold in extreme cases, *e.g.*, at the two ends of the diagram in Figure 6: the effect produced by adding 20% Manitoba to all-English flour is greater than that resulting from the addition of 20% all-English to Manitoba, although, of course, the two effects are of opposite character.

As a further illustration of the usefulness of this method of test baking, blends of a typical London flour (the basic grade flour referred to above) and an unusually good sample of Yeoman flour (1929 crop), will be discussed briefly.

The blends and tests, using the same technique as before with 1% yeast, were as follows:

	Blends	Fermentation periods	Best loaves thrown at
		hours	*hours*
A	X Flour alone	4 to 7	$6\frac{1}{4}$
B	90% X + 10% Yeoman	4 to 7	$6\frac{1}{4}$
C	80% X + 20% Yeoman	4 to 7	$6\frac{1}{4}$
D	70% X + 30% Yeoman	4 to 7	$6\frac{1}{4}$
E	60% X + 40% Yeoman	4 to 7	$6\frac{1}{4}$
F	50% X + 50% Yeoman	4 to 7	$6\frac{1}{4}$
G	40% X + 60% Yeoman	4 to 7	$6\frac{1}{4}$
H	30% X + 70% Yeoman	4 to $6\frac{1}{4}$	$6\frac{1}{4}$
J	20% X + 80% Yeoman	$3\frac{1}{4}$ to 7	$6\frac{1}{4}$
K	10% X + 90% Yeoman	$3\frac{1}{4}$ to 7	$6\frac{1}{4}$
L	Yeoman flour alone	$3\frac{1}{4}$ to 7	$6\frac{1}{4}$

The results are indicated diagrammatically in Figure 7. The best loaf in each blend was thrown at $6\frac{1}{4}$ hr. The best loaves were not, of course, equally good: dough body and stability and all loaf characters fell off slowly and progressively with increasing Yeoman content, and there were marked differences between the all-London flour and all-

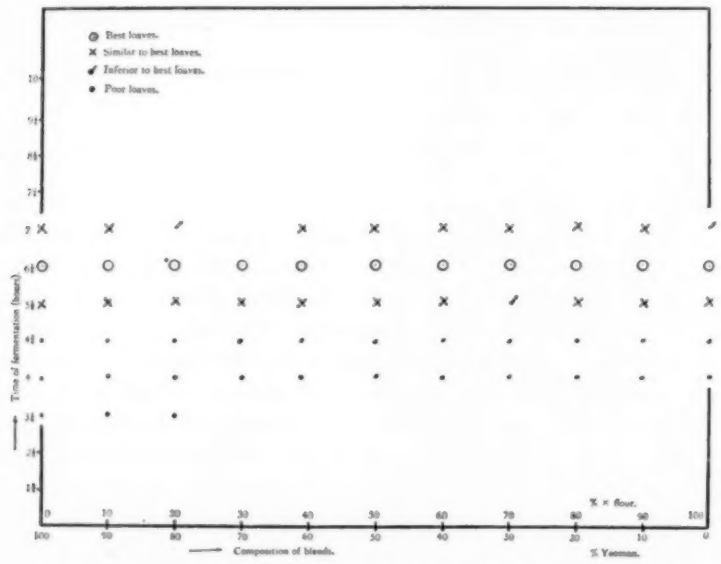

Figure 7. Baking quality of a London basic grade flour and Yeoman blends.

Yeoman doughs and loaves. This affords an interesting example of two flours differing considerably in "strength" (*i.e.*, in gluten quality as reflected in dough "body" and stability) and yet having similar fermentation times.

The results also suggested that some admixture with Yeoman tended to *increase* the fermentation time of the London flour, for, although all the best loaves were thrown at $6\frac{1}{4}$ hr., the 7-hr. loaves of the 90% to 50% London-Yeoman blends (blends B to F) were superior to the $5\frac{1}{2}$-hr. loaves, while the reverse was true of the all-London flour loaves. To test this point further, the London, the Yeoman, and the 50–50 blends were rebaked, using 2% yeast at $\frac{3}{4}$-hr. intervals and with fermentation times from $2\frac{1}{2}$ to $4\frac{3}{4}$ hr. The best Yeoman loaf was thrown at 4 hr., the $3\frac{1}{4}$- and $4\frac{3}{4}$-hr. loaves being definitely inferior. The best loaf from the London flour was thrown at 4 hr., the $3\frac{1}{4}$-hr. loaf being closely similar and the $4\frac{3}{4}$-hr. loaf definitely inferior. The best loaf from the blend was thrown at $4\frac{3}{4}$ hr., the 4-hr. loaf being distinctly inferior to the best. At the same time, the best blended loaf was inferior in general character to the best loaf from the London flour alone and superior to the best all-Yeoman loaf.

These results support the view that a blend of two dissimilar flours is not necessarily intermediate in all dough and loaf characters. In one or more characters, *e.g.*, fermentation time or tolerance or dough stability, a blend *may sometimes* be superior to the best of its constituents, although most of the characters would be intermediate.

The multiple differential system of test baking is necessarily elaborate and is not recommended for the purpose of controlling flour quality in a mill, the system of single test bakes being entirely adequate for this purpose. The differential system, however, is extremely valuable as an instrument of research. It would probably be impracticable with a small 4- or 6-loaf oven, but is not particularly time-consuming if adequate oven accommodation is available. It is also elastic and can be modified to suit particular requirements. It is rarely necessary to carry out so large a number of bakes as those described above in connection with the Manitoba-English blends. In testing flours from single wheats, for example, two sets of bakes are generally adequate for each flour, say, 12 to 15 loaves in all. The flour is first baked alone usually as cobs at $\frac{3}{4}$-hr. intervals in order to determine its proper time of fermentation and its fermentation tolerance. Five loaves are usually sufficient for this. This information will already have been obtained once and for all for the stock of reference flour. Blends of the reference flour and the flour to be tested containing different proportions of the latter, say, from 10% to 60%, are made and baked, usually as cobs, with a fixed fermentation time

which should approximate to that which is most suitable for the reference flour. The information obtained in this way is usually sufficient, but the method of course can be elaborated to any desired degree.

Summary

Work done in the writers' laboratories in the development of a satisfactory technique for test baking is described. The general principles of test baking are discussed briefly.

The relation between the percentage of yeast and time of fermentation is logarithmic; *i.e.*,

$$\frac{\log y_1 - \log y_2}{\log t_2 - \log t_1} = k$$

when y_1 and y_2 are the yeast percentages, t_1 and t_2 the corresponding times of fermentation for the best loaves obtainable, and k is a constant, the value of which will depend on such factors as kind of yeast, kind of flour, temperature of fermentation, *etc.*

It is further shown that although, in general, and as is well known, fermentation is more rapid the higher the temperature, this effect of temperature diminishes as the percentage of yeast is increased until, with 8% yeast, rate of ripening is independent of temperature over quite a wide range.

Size of dough may have marked effects on rate of fermentation. In any series of tests, therefore, it is desirable to make not one dough batch sufficient to make n loaves, but n separate single loaf doughs made at different times, so that all go to the oven together.

There are two main fields of activity in which test baking is an essential technique—mill control and flour research.

The objects are different in the two activities, and a baking technique entirely adequate in one may be quite unsuitable or even valueless in the other.

A system of single test bakes may be sufficient for mill control.

In flour research a more useful method is the *multiple differential* system of test baking: *multiple* because several simultaneous bakes are involved of progressively increasing severity, *differential* because an attempt is made to assess the flour's response to equal increments of severity of fermentation. The system enables clear and precise information to be obtained concerning:

(*a*) the intrinsic characters of dough and loaf,
(*b*) the length of fermentation required for the best loaf to be thrown,
(*c*) the fermentation tolerance,
(*d*) the response of any or all dough and loaf characters to additional variables, such as addition of improver or blending with varying proportions of other flours.

STUDIES ON TEST BAKING. II. DETERMINATION AND SIGNIFICANCE OF LOAF VOLUME [1]

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The Determination of Loaf Volume

An apparatus for measuring the volumes of loaves of commercial size was made in the writers' laboratories, and in its original form was similar in general construction to that described by Heon (1922). The apparatus was made of teak and consisted essentially of two boxes of about 9 inches square connected together by a vertical trunking about 4 inches square. The loaf was placed in the lower box on a false bottom consisting of a wire tray, the box being closed in front by a hinged door. The upper box contained a constant volume of seed which was allowed to fall, by releasing a wooden slide at the top of the trunking, on the loaf contained in the lower compartment. The seed fills the whole of the lower box not occupied by the loaf and extends upwards into the trunking, the upper level depending on the size of the loaf. The trunking is fitted in front with a glass panel, extending throughout its whole length, and a scale. The scale covers a volume of 1,500 cc. and reads arbitrarily from 2,300 to 3,800 cc. The apparatus may be calibrated by using an artificial wooden loaf [2] of known volume and adjusting the seed used until a correct reading is obtained on the scale, or by using any desired or convenient volume of seed with the wooden loaf and making a correction to the observed scale reading. The scale was graduated by determining the cross-sectional internal area of the trunking. After making a determination, the seed is removed from the loaf chamber by opening a slide at the bottom, and is poured back without loss into the upper chamber (with slide closed).

Rape seed, linseed, and wheat have been used with this apparatus. Rape seed has proved most generally useful.

The early results showed that differences in shape of actual loaves and slight differences in the position of the loaf in the container gave rise to considerable errors in the determination of loaf volume by this method. Apparently the shape of the top of the (tinned) loaf affected

[1] Issued for private circulation in 1930 as Confidential Report No. 19 of the Research Association of British Flour-Millers. Released for publication by the Council of the Research Association, 1935.

[2] For use of metal loaves for calibration purposes see Bailey (1930).

the packing very considerably and led to unreliable results. It was necessary to modify the apparatus and, in order to obtain a more uniform flow of seed, a metal cylindrical container having a funnel at the lower end was used instead of the upper wooden box. It was fixed rigidly into the upper box with the spout of the funnel protruding downwards into the connecting trunking. A glass bulb, which could be lifted by means of a string, fitting loosely into the funnel spout, served as a valve in lieu of the upper wooden slide. Further, a baffle was inserted between the falling seed and the loaf so that the seed should fall around the loaf and not directly on it. The metal baffle was constructed in the shape of a triangular pyramid, the apex being directly in the path of the falling seed. The reproducibility of results under the new conditions (using the baffle) was determined using the same commercial tinned loaf and linseed, rape seed, and wheat. The actual readings were quite arbitrary, as different amounts of seed were used in the three series. The results are given in Table I. The results

TABLE I

EFFECT OF POSITION OF LOAF ON VOLUME READINGS

End-on centrally	Reversed	Moved appreciably—		At an angle to normal central position	
		To right	To left	30°	90°
Cc.	*Cc.*	*Cc.*	*Cc.*	*Cc.*	*Cc.*
Linseed					
2,420	2,430	2.435	2.430	2.375	2.300
2,420	2.425	2.430	2.435	2.385	2.310
2.430	2.425	2.430	2.435	2.390	2.315
Rape seed					
2,475	2.480	2.480	2.480	2.480	—
2,485	2.480	2.475	2.485	2,475	—
2.480	2,475	—	—	—	—
Wheat					
2,425	2.430	2.435	2.430	2.420	—
2,435	2.435	2.425	2.425	2.410	—
2.425	2,425	—	—	2,405	—

are exceptionally good. With the loaf in a more or less central position replicate readings did not vary by more than 15 cc. Two similar series of determinations on two other loaves were equally satisfactory.

Below are given the results of three series of determinations on each of five commercial 2-lb. loaves made from different flours in tins of similar size and shape. The determinations were made with rape seed, linseed, and wheat; the scale readings for the standard wooden loaf being determined in each case. Replicate readings on the latter

showed a range of variation of only 10 cc. The corrections obtained from the scale readings and the actual known volume of the wooden loaf have been applied in Table II, which therefore records correct average volumes:

TABLE II

MEAN VOLUMES AFTER CORRECTIONS[1]

Loaf No.	Rape seed	Wheat	Linseed
	Cc.	*Cc.*	*Cc.*
1	3,280	3,300	3,280
2	2,790	2,795	2,775
3	2,715	2,715	2,710
4	2,495	2,480	2,460
5	2,250	2,240	2,215

[1] Each mean volume is the mean of two determinations, one with the loaf placed centrally and end-on, and one with the loaf reversed.

These results show excellent agreement, the differences between the mean volumes of any one loaf varying only from 5 to 35 cc.

It was thought desirable to ascertain whether differences in loaf volumes of a set of loaves measured in one position in the apparatus agreed with the differences observed when the same loaves were measured in a different position, *e.g.*, with the loaves in a central end-on position and at right angles to this position respectively. Using rape seed the results were as follows:

TABLE III

EFFECT OF POSITION OF LOAF ON VOLUME READINGS

	Central end-on	At right angles	Difference
	Cc.	*Cc.*	*Cc.*
Wooden loaf	3,430	3,350	80
Loaf A	3,230	3,150	80
Loaf B	3,265	3,170	95
Loaf C	3,090	3,005	85

Since rotating the loaf through 90° caused a difference in apparent loaf volume of 85 cc. the effect of changing position of loaf on closeness of packing of the seed (under the present experimental conditions) is small and constant. Accordingly, the relatively slight differences in shape of tinned loaves of unequal volume should cause only very small errors in the determination. This conclusion is further strengthened by the fact recorded above, that three such widely different types of seed as rape seed, linseed, and wheat record the same volume for individual loaves.

Further, the volumes of the three standard wooden loaves were determined in the apparatus using rape seed, the volume of seed being

adjusted to give a correct reading for the cob loaf. The results were as follows:

	Cob	Tinned	Cottage
True volume, *cc.*	2,840	3,410	3,295
Apparent volumes in apparatus with rape seed, *cc.*	2,840 2,855 2,830 2,830	3,340 3,350 3,345 —	3,480 3,490 3,480 —
Mean volume, *cc.*	2,840	3,345	3,485

The difference in shape between the cob and tinned loaves resulted in a tighter packing of the seed in the latter case resulting in a mean estimated volume of the tinned loaf of 65 cc. (about 2%) less than the true volume. The shape of the cottage loaf apparently results in much looser packing of the seed, the estimated volume being 190 cc. (about 6%) more than the true volume. The results certainly support the assumption that equal packing of the seed would occur with any particular type of loaf, and that the error due to inequalities in packing (under the writers' experimental conditions) is small.

Reproducibility of results with four cob loaves using the three types of seed was investigated. Four determinations were made on each loaf, the loaf being rotated through 90° after each reading. The corrections deduced from the standard loaf scale readings were applied in each case so that absolute and comparable values were obtained. The linseed gave erratic results; maximum differences between replicate values of 120 cc. were obtained. The results, using rape seed and wheat, are given below:

Loaf	Rape seed, *cc.*	Wheat, *cc.*
1	2,890 2,920 2,930 2,915 } mean = 2,915 range = 40	2,930 2,910 2,870 2,940 } mean = 2,910 range = 70
2	3,000 2,950 2,965 2,970 } mean = 2,970 range = 50	2,950 2,980 2,990 2,990 } mean = 2,980 range = 40
3	3,110 3,100 3,120 3,110 } mean = 3,110 range = 20	3,140 3,135 3,095 3,050 } mean = 3,130 range = 55
4	3,230 3,200 3,270 3,220 } mean = 3,230 range = 70	3,250 3,320 3,240 3,240 } mean = 3,260 range = 80

The results discussed above indicate that, with the writers' apparatus and experimental technique, determinations of loaf volume may be made with reasonable precision. With tinned loaves the range of variation of any number of replicate determinations on the same loaf should not exceed 1% of the mean value and is usually less than this, being probably nearer ½%. With cobs and cottages the range of variation among replicate determinations is greater and may be as high as 2% or 2½%, although usually less than this. It must be emphasised that this degree of precision applies only to replicate determinations of volume carried out on one and the same loaf. As will be shown later, the range of variation of actual loaf volume of replicate loaves made at one time from the same lot of flour is very much greater, being of the order of 10% or 15% of the mean value. For further discussion of loaf volume measurements and factors affecting them see Whitcomb (1925) and Strube and Luster (1932).

Simpler Methods of Estimating Loaf Size: Measurements of Loaf Perimeters and of Areas of Cross-Section

Before the above technique for measuring loaf volume was worked out, two simpler methods of measuring loaf size were in use in these laboratories, one developed by the writers and the other by Holger Jørgensen in Denmark. The former method consisted in cutting the tinned loaf in two, symmetrically and transversely, placing the loaf with cut surface downwards on a sheet of paper, drawing its contour and measuring the area of the drawn figure with a planimeter.

Jørgensen's (1930) method consists of putting a tape around the tinned loaf and measuring the greatest circumference, or perimeter, both longitudinally and transversely and using the sum of the two measurements (called Σp for short) as a measure of loaf size.

Both area of transverse cross-section and the sum of perimeters are very easily and quickly measured, and in the case of regular geometrical solids of similar shape, *e.g.*, cubes of various sizes, each measurement bears a definite relation to the volume, and should therefore serve as a measure of *relative* volume. In the case of tinned loaves, however, differences in size and shape of the top and irregularities of face and crust would undoubtedly introduce some error. In view of the ease and simplicity of the two determinations it seemed worth while to ascertain the precise mathematical relationship between the sum of the perimeters and the cross-section on the one hand, and actual loaf volume on the other. For this purpose measurements were made of 97 tinned loaves of various flours baked at different times by various processes in tins of the same size and shape. The detailed measurements are given in Table IV and the sums of the perimeters

TABLE IV

VOLUMES, PERIMETERS AND AREAS OF CROSS-SECTION OF TINNED LOAVES MADE AT VARIOUS TIMES FROM VARIOUS FLOURS[1]

Volume	Σp	Area	Volume	Σp	Area
Cc.	*Inches*	*Square inches*	*Cc.*	*Inches*	*Square inches*
3,775	51.9	35.1	3,025	48.2	29.2
3,775	52	35.3	3,020	—	29.2
3,775	52.6	34.3	3,010	49	—
3,635	53.4	—	3,010	48.7	30.2
3,595	52.4	34.8	3,010	48.1	27.7
3,565	52.1	34.2	3,005	48	29.8
3,520	51	34.6	3,005	48.1	27.2
3,515	51.1	34.7	3,000	48.2	28.6
3,495	50.6	34.4	2,990	48.1	29.9
3,440	50.1	31.7	2,980	47.1	27.8
3,440	51	32.3	2,975	47.4	27.7
3,430	50.9	32.9	2,970	48.1	28.7
3,420	50.7	33.3	2,970	49	—
3,410	50.1	32.5	2,955	49.1	30.9
3,405	49.9	31.9	2,955	47.5	—
3,400	51	31.5	2,955	48.9	—
3,390	51.2	33.1	2,940	47.4	27.3
3,385	50.4	30.3	2,935	47.4	28.0
3,380	50.6	32.1	2,905	47.5	—
3,380	50.5	32.0	2,895	46.7	27.1
3,375	50.1	33.2	2,870	46.9	28.3
3,375	49.7	31.1	2,840	47.7	27.8
3,330	50.1	31.6	2,805	47.5	—
3,290	49.7	31.3	2,790	46.5	—
3,285	49.4	31.3	2,770	46.7	26.8
3,280	49.7	—	2,770	45.6	27.1
3,275	50.6	30.4	2,770	46.6	27.1
3,255	49.5	31.1	2,765	46.7	—
3,230	49.7	32.3	2,760	46.4	—
3,215	49.5	31.4	2,755	47	26.4
3,200	49.2	30.5	2,745	46.6	27.5
3,175	49.2	29.3	2,740	46.2	26.7
3,160	49.1	29.6	2,740	46.4	25.1
3,150	49	30.7	2,735	45.9	26.6
3,115	48.4	30.1	2,715	46.1	—
3,115	48.7	30.1	2,700	46.1	26.8
3,105	49.1	30.8	2,690	45.7	—
3,105	49.9	29.1	2,685	46.5	26.1
3,105	49.6	28.8	2,680	45.7	26.2
3,100	48.6	—	2,675	45.9	25.1
3,095	49.1	29.7	2,675	46.5	26.6
3,080	48.7	30.0	2,665	—	26.4
3,075	—	28.9	2,660	46.2	26.9
3,055	48.2	28.4	2,545	45.5	24.3
3,045	49.2	—	2,535	44.7	25.6
3,045	48.9	29.9	2,525	—	25.8
3,035	48.5	29.6	2,495	44.1	—
3,030	—	29.7	2,250	43.1	—
			2,200	—	23.2

[1] These data were used for calculating the coefficients of correlation between loaf volume on the one hand and loaf perimeters and areas of cross-section on the other.

(Σp) are plotted against loaf volume in Figure 1. It will be noticed that the points in Figure 1 are rather closely distributed along a straight line indicating a close correlation between the two quantities loaf volume and Σp. Moreover, the points for loaves with uneven, torn,

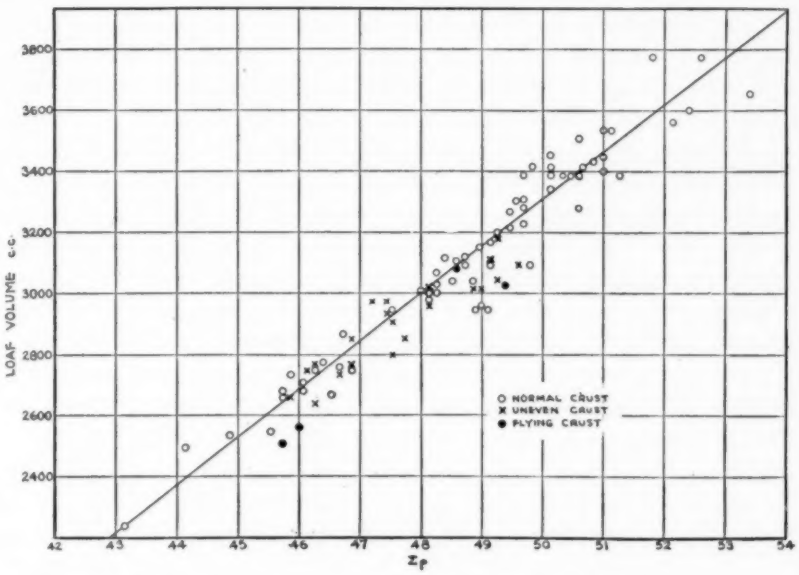

Figure 1. Showing the relationship between loaf volume on the sum of the loaf perimeters.

broken, or flying crusts are just as near to the straight line as are the points for normal loaves, so that no additional error appears to be introduced through marked irregularities of crust. The *correlation coefficient* between loaf volume and the sum of the perimeters was 0.963 with a probable error of $\pm$ 0.0051; and that between loaf volume and area of cross section of the loaf was 0.950 with a probable error of $\pm$ 0.0073. Now the facts that the correlation coefficients are very nearly equal to unity, and are almost 200 times greater than their probable errors, indicate that the area of cross-section or the sum of the two perimeters of a tinned loaf should be as accurate a measurement of the loaf size as its loaf volume.

The Significance of Loaf Volume Measurements

Experience has convinced the writers that loaf volume, in spite of its popularity in many quarters, is not a good criterion of flour quality. The ability to produce a relatively larger loaf than some other flour is merely one character. As one of us has written elsewhere (see Fisher, 1935): if the factors of good quality "are present in a flour to a high

degree, the dough will behave well in the bakehouse and satisfactory, even excellent, bread will result. It is true that a large loaf is desirable. A large loaf will make a stronger appeal to the purchaser than a small one, but mainly because large size is associated in the purchaser's mind with excellence in other qualities. This may be illustrated by making a dough from a straight run Manitoba flour, say with ½% yeast at a temperature of 80°, and baking a loaf at hourly intervals, say, from one to twelve hours. The loaves will improve steadily in all characters up to a maximum, after which loaf quality will fall off more or less rapidly. Almost invariably the best loaf in all other characters will be the biggest. A similar relation will be observed with an all-English Yeoman flour, although the best loaf in this instance will be thrown earlier than with the Manitoba. Now, the difference in volume between the best Manitoba and English (tinned) loaves might be comparatively small and would afford no indication of the very marked differences in dough toughness and stability." To repeat: loaf volume is not a safe criterion of flour quality; it is only one character of many. It has made a strong appeal to many investigators possibly because it is one of the few dough or loaf characters that can be measured with some approach to accuracy, although, as has been shown above, this approach is not very close. What is needed are methods of measuring *all* dough and loaf characters—water absorption, elasticity, viscosity, extensibility of dough, oven spring, and grain, softness, texture, and spring of loaf crumb. As one step in this direction the writers recommend the making of cob loaves, in addition to tinned, since such loaves afford visual demonstration of differences in stability and oven spring: the better the stability the less will be the spreading or squatting of the doughs on the tray during final proof, and the less consequently will be the horizontal diameter of the resulting cob loaf. Similarly the height of the loaf is a good indication of oven spring.

Strictly speaking, oven spring should be measured by the difference in height between loaf and dough, rather than by the height of the loaf alone. Oven spring, however, is important in so far as it is a main factor in the production of a large loaf of light crumb. Consequently the height of the loaf appears to be a more useful measurement than the more theoretical and academic, and perhaps more strictly logical, one of real oven spring. Moreover, this measurement should be considered in conjunction with the horizontal diameter of the loaf: the two together afford as good an idea of loaf size, bulk, or boldness as the sum of the perimeters does in the case of a tinned loaf.

The horizontal diameter of a cob loaf alone affords a good *practical* indication of dough stability: the greater the loaf diameter the poorer

the dough stability. Here again diameter is not a strict measurement of stability. When a dough "springs" in the oven the walls of the dough are pulled inwards to some extent, the extent being greater the greater the spring. Consequently of two cob doughs of precisely similar stability, *e.g.*, of equal dough diameters, the one with the greater oven spring will show the smaller loaf diameter. Here again, however, we are concerned with a measurement of practical rather than theoretical interest: stability is important in so far as it is the main character contributing to the production of a large well-piled cob or cottage loaf. The horizontal diameter of the loaf, especially when considered in relation to the height, is a good practical indication of dough stability. The two measurements together yield more information than loaf volume and are more easily made.

For reasons apparent from the above considerations the ratio of height to horizontal diameter used by some workers is not as useful or as illuminating as the two constituent measurements.

Summary

An apparatus is described for the determination of loaf volume.

It has been shown by means of this apparatus that the determination of loaf volume is seriously affected by a number of factors, chief of which are type of seed used, the manner in which the seed is allowed to enter the loaf chamber, the shape of the loaf (*e.g.*, whether tinned, cob, or cottage) and the position of the loaf in the chamber. With these conditions standardised, determinations of loaf volume may be made with fair precision. With tinned loaves the range of variation of replicate determinations on the same loaf need not exceed 1% of the mean value and is usually nearer $\frac{1}{2}$%. With cobs and cottages the range of variation may be as high as 2% or $2\frac{1}{2}$%.

Useful determinations are the measurements of the horizontal and vertical diameters of cut cob loaf. The horizontal diameter affords a good practical indication of dough stability and the vertical diameter an indication of oven spring.

Jørgensen's method of measuring the greatest circumference of a tinned loaf both longitudinally and transversely is a simple, rapid and sufficiently accurate method of determination of loaf size. The sum of the two perimeters is closely correlated with loaf volume, the correlation coefficient being 0.963 ± 0.005.

Many of the measurements recorded in this report were made by S. F. Hines, B.Sc.

Literature Cited

Bailey, C. H.
1930 Calibration of loaf volume measuring devices with metal models. Cereal Chem. **7**: 346–348.
Fisher, E. A.
1935 Flour Quality. Second edition. Technical Education Pamphlet No. 3, published by National Joint Industrial Council for the Flour Milling Industry, London (p. 34).
Heon, A. A.
1922 A bread measuring device. J. Am. Assoc. Cereal Chem. **7**: 152.
Jørgensen, Holger
1930 Beretning om Undersøgelser af dansk Hvede af Høsten, 1929, p. 25.
Strube, J., and Luster, G.
1932 Zur methodite des backversuches. Z. ges. Getreide- u. Mühlenw., **19**: 115.
Whitcomb, W. O.
1925 A study of methods of determining the loaf volume of bread. Cereal Chem., **2**: 305–310.

STUDIES ON TEST BAKING. III. THE HUMAN FACTOR IN TEST BAKING. A PSYCHOLOGICAL STUDY

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In an inquiry into the physical properties of various doughs Halton and Scott Blair[2] endeavoured to correlate these physical properties not only with the breadmaking qualities but also with the "feel" of the dough when handled by the baker in the bakehouse. I give a quotation from a letter from Scott Blair to me in which he referred to that inquiry: "It seems as though differences in certain physical properties are much more easily observed by feel than is the case with others. For example we suspect that the hand is comparatively sensitive to changes in elasticity modulus, but insensitive to changes of viscosity."

The following observations and experiments were made with a view firstly to obtain some psychological understanding of how the baker works in judging doughs in the bakehouse, and secondly to compare the reliability of the subjective methods of the baker and the objective methods of the physicist in examining doughs of different properties.

Complaints made by bakers concerning the properties of flour are based frequently on the subjective impressions which the baker gets when making the dough. With reference to these subjective impressions it is of prime importance to find out their exact degree of reliability by means of psychological experiments. For it is only by such

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[2] Halton, P., and Scott Blair, G. W. A study of some physical properties of flour doughs in relation to their breadmaking qualities. Cereal Chem. **14**: 14: 201–219 (1937).

an examination that the value of a baker's complaints concerning the quality of a flour (based, as many of them are, on subjective impressions) can be assessed.

For analysing the human factor in making doughs, four different problems have to be considered:

(1) The baker has developed (as workers in other callings have done) special terms for characterising his products and raw materials. Some of his terms used for describing doughs can be understood by the layman without difficulty; others have a more hidden meaning. Different bakers use some of these terms in different ways. Our first important task is to analyze the exact meanings of these terms and to find out whether and to what extent they may be used also for the scientific characterization of doughs.

(2) We cannot understand the exact meaning of the baker's judgments about doughs unless we analyse his judgments psychologically. Which sense impressions are the basis of his judgments and how do the various senses co-operate? This question of course cannot be answered by simply asking the baker for an analysis of his impressions, but only by observing the baker's response when the various conditions in handling the doughs are changed.

Besides that, trained psychologists must be asked to describe and analyze their own sense-impressions when handling various doughs.

(3) A first step into the question of the baker's reliability in judging doughs can be made without leaving the subjective realm. It is quite obvious that we could have only little confidence in the baker's subjective judgments if we were to find that either the judgments made by the same baker with reference to the same dough on different occasions showed no good agreement, or that the judgments made by different bakers with reference to the same doughs were not in agreement. It is obvious that only bakers of long experience and generally acknowledged reliability ought to be used for the two categories of experiments suggested here. If these experiments led to unsatisfactory results a sceptical attitude towards the subjective judgments of bakers generally would have to be adopted and the need for physical methods of testing the properties of doughs would be still more urgent than has been recognised up to now.

(4) We have also to carry out experiments about certain judgments of the baker. To what extent is the baker successful in distinguishing various doughs, whose differences, *e.g.*, elasticity and viscosity, can be defined in an objective way. These experiments should lead to a clear decision as to whether the physicist's objective methods are superior to the baker's subjective ones.

1. Terms Used by the Baker for Characterising Flour-doughs

A few words about the conditions under which the baker has to make his statements. The baker is in the habit of judging the dough when he is kneading it on a table. For a closer estimation the baker takes the dough off the table and manipulates it, *e.g.*, shakes it or pulls it, between his hands. The stretching of the dough between the two hands with the effect that a ribbon of dough comes into existence is of special importance. It is important from the psychological point of view to distinguish these different ways in which the baker handles the dough because different groups of muscles and different sense organs, or at least muscles and sense organs in different combinations, are used on these various occasions. Corresponding to these differences, different properties of the dough are judged by the baker.

The doughs used in the following experiments were either prepared by the bakers themselves or were presented to the bakers after having been made by others. In this section we shall deal with freshly made, unfermented, *i.e.*, unyeasted, doughs; for this reason we will analyse only those terms which refer to unfermented doughs.

For a full understanding of the following characterisations it is necessary to realize that two different categories of judgments exist, which we will call absolute and relative judgments. An absolute judgment is defined in psychology as a judgment, the object of which is one single thing; *e.g.*, a single kind of flour. For a relative judgment two or more objects (*e.g.*, doughs) are compared with reference to certain properties.

There exist two categories of absolute judgments. The characterisation of a dough can take place either in a general way, or more precisely in relation to former experiences in considering certain kinds of dough. I begin by quoting a series of judgments made by two experienced test bakers—S and C—when shown single types of dough.

Absolute judgments of general character:—S: (1) Very good body, tough, good spring, not short, immature. (2) Good body, very fair spring, clay-like, good extensibility, immature. (3) Fairly good body, good spring, good extensibility. (4) Good body, good extensibility, good spring. C: (1) It feels like a weak flour. Not strong gluten content. Not very tough, not very resilient. (2) Strong good gluten content, good colour, good elasticity. (3) Strong flour, *i.e.*, a good gluten content, good elasticity, good ductility.

Absolute judgments of specific character, i.e., referring to certain types of doughs:—S: Like a Manitoba . . . English . . . Miller's Mixture.

Relative judgments: Doughs made of (*a*) English, (*b*) Australian, (*c*) Miller's Mixture had to be compared by C. We got the following relative judgments. (*a*) more clay-like than (*b*); (*b*) more resilient

than (*a*); (*b*) stronger flour than (*a*); (*a*) more ductile than (*b*); (*a*) tougher than (*b*); (*b*) better ductility than (*c*); (*b*) breaks quicker than (*a*); (*b*) better colour, tougher, more spring than (*a*).

Whereas all the terms mentioned above seem to be used quite regularly by all bakers, there exist others which we meet more seldom and which are only used by individual bakers. They are taken from reports of four further bakers interviewed by the St. Albans laboratory staff. The judgments are of an absolute and general type: *Lively:* dough that is kind and on moist side; comes to moulding table full of life. *Wiry:* A dough that is full of stretch and pull, usually on greasy side; especially in Manitoba flour. *Size:* synonymous with body. *Bounce:* a dough full of life and resilience, seems to grow under your hand and comes back to you when moulding. *Firmness:* a compound quality relating to water absorption, gluten quantity and quality. *Resistance:* the amount of pressure required to expel gasses generated during fermentation by moulding or knocking back.

We have to try to systematise the above mentioned terms. If we are right in supposing that the baker in describing a dough will begin with that quality which seems to him to be the most important one we must say that for one experienced baker the most important property of doughs is that which he characterizes as (very good,fairly good, or poor) *body*. What does *body* with its different attributes really mean? This question is double-sided; what does the baker understand by body, and how does that property become manifest to him. It seems to be beyond all doubt that in an objective sense the baker in using the term body aims at describing the essential nature or character of the dough, a character which is bound up with the quality and quantity of gluten in the dough or flour respectively. This becomes particularly obvious in the statements of baker C, who in the first place speaks about the gluten content of the dough where baker S uses the term body. And with the gluten content of the flour is linked up its water absorption, that property which is so important for the baker's handling of the dough. The baker is very likely to believe that he can directly perceive the degree of gluten content of the dough, but this is of course nothing but an illusion. In reality the baker has certain specific impressions, from which he draws his conclusions concerning the gluten content. So we come to the question: what sense-impressions give the baker the clues for his judgment about body? I think body includes four different properties which can be sensually perceived: (1) *The degree of stickiness.* A good body is characterised by the fact that the dough has a minimum of stickiness. A dough of good body must not be too dry nor too runny; the optimum water absorption is in between, where there is a hardly

appreciable degree of stickiness. Such a dough by possessing a relatively inappreciable degree of stickiness may be called a dry dough. (2) *The degree of elasticity.* The elasticity has many degrees, from a high to a low one. Almost synonymous with elasticity are used the terms spring, resilience, liveliness. The contrary of elastic is clay-like, dead or plastic. One of the bakers spoke about bounce instead of elasticity. (3) *The degree of toughness or firmness.* One baker uses wiry as synonymous with tough. The opposite of toughness is tenderness. The toughness of a dough is particularly appreciated when the dough is torn between the two hands. (4) *The degree of extensibility or ductility.* The opposite of ductility is shortness; a short dough breaks when it is stretched. It is a certain combination of the above mentioned four qualities which characterises body of a dough. But the properties 1, 2, and 3 are more important than the 4th, because they can more easily be perceived by sense-impressions.

An individual baker in judging the body of a dough will doubtless pay more attention to one of the four properties mentioned than to the others. Consequently, different bakers' ideas of body will not be precisely identical. This is not very important. What is much more important is the statement that behind this term body there is not concealed a new property or any particular property of the dough. Body is no doubt a good shorthand term for the bakehouse, one which will generally be understood very well. For this reason there is no objection to be made against its continued use by the baker. But the term cannot be used for scientific purposes. We will renounce in this paper the use of this term and shall prefer to make use of the above mentioned four terms which suffice completely for the characterisation of doughs.

2. On What Sense-impressions does the Baker Rely in Judging Doughs?

One might expect that the baker relies exclusively on the sense of touch in judging the dough, but this is not the case; vision plays an important part too. The sense of hearing makes only a small contribution. Amongst the senses of the skin that of temperature is more important than one might think. Although dough, even if it contains no yeast, has a marked smell, I made no observations suggesting that the baker makes any use of the sense of smell except in those cases where obvious taints were present.

We have now to enter on a more thorough study of the contributions of the aforementioned senses which help the baker in judging doughs.

Vision. If the baker has to make the doughs himself he has a

chance to see certain optical differences in the flours he uses. These differences concern the colour of the flours as well as their structures. Very often the colour of a flour gives the baker a clue concerning the origin of the flour. But the colour of a flour may influence the judgment of a baker even if it is not particularly mentioned by the baker. As to the structure of a flour we have to distinguish two ways in which it becomes manifest, firstly, the so-called macrostructure of the flour particles (*e.g.*, their size, shape, *etc.*), and, secondly, the microstructure or fine inner structure of the individual particles themselves. Thus, if one has to see and feel the flat surfaces of metal, wood, paper, leather, one's reactions are different in the four cases. Although all four surfaces may be flat and smooth all are obviously different and our visual and tactile impressions are also different. These differences are due to the fine internal structure (or microstructure) of the materials. Hence, the "handle" or "liveliness" of flour is due not only to the granularity (macrostructure) but to the fine microstructure as well.

If the baker has to judge a dough which he has not made himself, he can again judge by vision the two properties of the dough—colour and structure. During my observations, differences in colour of various doughs have not been mentioned by bakers but that does not mean that no attention was paid to them by the bakers concerned. It is beyond all doubt that the baker takes many things into consideration in the optical impressions which he gets from structural differences between doughs. While the baker is manipulating the dough he continually tests or controls it by vision. The changes in structure which take place when the dough is being manipulated are of much greater importance than the structure of the dough at rest. The baker sees how and to what degree the dough resists a change in structure by manipulation. By vision the baker becomes aware of the amount of recovery and can take this amount as a certain measure of elasticity. The baker sees how the dough stretches when it is pulled and how it eventually breaks; so ductility and toughness can within certain limits be directly perceived by vision. The real importance of optical impressions can be tested by two categories of experiments. We can either ask the baker to judge various doughs by handling with his eyes closed, or we can ask him to judge doughs by vision when not he himself but someone else is handling the doughs. I have carried out both kinds of experiments with C. Even if he had to judge the doughs by handling, but with his eyes closed, he succeeded very well in doing so. And the same was the case when he had to form an opinion of the elasticity, toughness, and ductility of doughs through visual impressions, when I was handling the dough before his eyes. From these

two sets of experiments we may conclude on the one hand that the baker in judging doughs is not absolutely lost without vision, but on the other hand he can make the optical impressions the only ones to rely on if we want him to do so. Psychologically the sense of vision is very likely to be educated by the sense of touch.

Sense of hearing. Modern psychologists know that the auditory impressions which we get in handling objects are much more important as aids to our judgments of the properties of these objects than was formerly realised. It is possible that the auditory impressions which the baker gets in handling doughs are not entirely unimportant for his judgments. But I cannot say whether various doughs give various auditory impressions. I may, however, refer to a remark of one baker: "A dough of good gluten quality squeaks under the hand."

Sense of temperature. The impressions of temperature which arise from an object are dependent on its heat-conducting property, its specific temperature, its heat capacity, and the structure of its surface. Flour feels rather cool, cooler for instance than wood. Dough feels cooler than flour of which it is made, and bread feels warmer than dough. It is beyond all doubt that the total impression which we get from dough when touching it is very strongly influenced by the temperature impression. In the impression of stickiness we have coolness as an important component. There is a large subjective element in stickiness; a sticky thing feels *cool* and an actual change of temperature of the sticky thing will modify materially the intensity of the impression. For example, the higher the temperature the less sticky a dough will feel, the lower the temperature the greater the apparent (not the real) stickiness. Again, the impression of stickiness is least when the dough or other sticky substance is at the same temperature as the hand. Higher degrees of stickiness on the other hand involve a greater area of contact or closer contact between the dough and the hand, and in this way strengthen the impression of coolness. Incidentally, I have got the impression that doughs of higher absorption feel somewhat cooler, but no temperature readings were actually taken. So, *e.g.*, Manitoba dough feels cooler than an English. This is rather surprising since if both doughs were made with the same liquor the Manitoba dough (of the highest absorption) would be expected to have actually the higher temperature. In connection with this difference there seems to exist a slight illusion of weight. The cooler Manitoba seems to be, *i.e.*, feels, a little lighter than the English of the same objective weight.

Sense organs of the skin, the muscles, sinews, and joints. In handling the dough only the fingers come in direct contact with it. This contact

leads to a stimulation of the sense of touch. But indirectly the sense-organs in the muscles, sinews, and joints of the hand, the fore-arm, the upper arm, and the shoulder are stimulated too. We may even say that in handling big masses of dough the muscles of the back of the baker participate in the work. The stimulation of all the innumerable sense organs which come into play gives rise to certain subjective impressions such as strain or fatigue, coolness, and/or roughness on the one hand, which give rise to an impression of certain objective properties of the dough on the other hand.

The most important property of the dough which is perceived by the sense of touch is the stickiness. We shall find that the sensitivity of the sense of touch is especially high for different degrees of stickiness. It is worth mentioning that nobody likes to touch sticky things. This general feeling of unpleasantness towards sticky things is very likely to be an important factor in the tendency of the baker to make his dough as little sticky as possible.

We know that most properties of things which stimulate the sense organs of the skin, the muscles, the sinews, and the joints, do so only if a movement of the hand relative to the object takes place, or *vice versa*. So the properties of dough, such as elasticity, ductility, and toughness become manifest only if a relative movement takes place. It is not paradoxical that the physicist and the psychologist respectively may require a different number of properties or even different properties of the dough in order to provide a full characterisation of a dough in their respective spheres. For, as a matter of fact, it has been known to the psychologist for a long time that the number of properties of the stimulus, *e.g.*, of the dough, do not always correspond to the number of (psychological) properties of the sense impression brought about by it. (The best known example of this kind is to be found in the field of hearing.) The psychological properties, *e.g.*, body and spring, do not correspond to the physical properties of viscosity, elasticity, *etc.*, but are rather the result of a complicated cooperation of the different senses of the skin, the muscles, the sinews, and the joints. Thus, it would be a mistake to suppose that in the property which the baker calls elasticity or spring the pure physical elasticity alone is manifest, or that in the property which the baker calls toughness the pure physical viscosity alone is revealed. Rather, physical elasticity and viscosity are always co-operating in producing what the baker, when handling the dough in different ways, calls elasticity (or spring) and toughness respectively. It has been shown indeed by the recent physical investigations of Halton and Scott Blair that the baker's impression of spring is very probably connected with the *ratio* of dough viscosity to elasticity and not to the absolute elasticity alone.

As to the temporal (time) factor which enters into all the performances of the baker we must not forget that, in contrast to what holds good in physics, temporal proceedings in physiology can only be perceived when they are not too fast and not too slow. So, *e. g.*, the temporal changes which take place in the doughs used by Halton and Scott Blair in their physical inquiry (such as the fall in viscosity and elasticity with time) could not possibly be perceived directly in a psychological sense owing to the slowness of the change.

A striking example of this may be cited from the work of Halton and Scott Blair. Bakers maintain that Manitoba doughs improve in body as fermentation progresses. This toughening of dough during fermentation is associated by bakers with high quality and is a property they expect in Manitoba flour. Actually no such toughening occurs and could not be *directly* perceived by the baker if it did occur owing to the slowness of the change. Actually all doughs soften during fermentation, some to a greater degree than others. When a baker handles a number of doughs at the same time those which soften least appear to be getting tougher in comparison with those doughs which soften more rapidly. (This is an example of the relative judgments referred to on p. 384.) Hence the impression is gained (and has become widespread among bakers) that some doughs actually toughen during fermentation, an impression that is undoubtedly mere hallucination. This can be tested very simply in any bakery; if two Manitoba doughs from the same bag are made at an interval of some hours the younger dough will always feel the tougher if they are moulded at the same time, one in each hand.

It is evident that one would be mistaken in supposing that the impressions of elasticity, toughness, and ductility, which can be distinguished by the baker, are distinctly separated from each other; the baker rather gets a total impression of a general and somewhat vague character although he can analyse this total impression within certain limits, ill defined, by changing his ways of handling the dough. Of course the baker's analysis has nothing to do with the analysis of the psychologist.

Neither in the physical range of elasticity nor in that of viscosity do there exist any discontinuities, *e.g.*, a dough may be more or less viscous, more or less elastic, and the differences may be made as small as one wishes by, for example, blending flours. There are not two opposite classes of, say, viscous and non-viscous doughs. For the baker, however, there exist specific and apparently opposed differences in doughs. The baker speaks about doughs which are lively on the one hand and clay-like or dead on the other. I think it can be proved that this difference is based upon an interesting co-ordination of the

antagonistic muscles. Every impulse to move a muscle is followed by a reflex impulse to move its antagonistic muscles. A very simple observation may serve as a demonstration of this physiological level. If one opens the hand and moves the fingers quickly against or towards each other they will show a short opposite movement independent of our will. This latter move takes place in a reflex way, *i.e.*, it occurs apparently automatically and is quite beyond our control. Let us suppose that the movement of our fingers is not made against empty space but against a dough which is brought in between the fingers. In a case like that an elastic dough will help the reflex movement whereas a dough of poor elasticity will hamper it. For this reason an elastic dough will give the impression of being full of life whereas a dough of poor elasticity will appear dead.

A very important consideration is that the experienced baker is not controlled exclusively in his judgments by the actual sense-impressions which he gets in handling the dough; but innumerable earlier experiences of similar and other doughs come into play and contribute to his final judgment. Only too often these earlier experiences may even work as prejudices. If the baker knows the origin of his flour he will expect certain properties in the dough made from it. But even if we do not tell him the brand of the flour, the colour and structure of the flour and the absorption of water will give him important clues by which to form his judgment. He will be inclined to cling to the judgments about apparently similar doughs made on earlier occasions. He feels the dough, so to speak, through or by means of his old experiences. One can try to exclude this factor of experience by carrying out experiments where the baker is given the dough and not the flour. But even then we cannot prevent the baker from making certain suppositions. This holds good particularly the more experienced the baker is. As to the consequences we have to draw from this fact, we cannot avoid the supposition that the judgments of the baker appear on the whole to be more certain than they really are. Anyhow, in experiments of this kind we have always to take into account the previous experiences of the baker; and from the scientific point of view these experiences will to a certain and more or less marked degree act as prejudices. We will mention again an observation discussed above (p. 390) which probably can only be explained by the existence of a prejudice of this kind. Bakers occasionally attest that Manitoba dough after some hours of fermentation is more wiry than the same dough freshly made. Physical methods of examination provide evidence that such is not the case; dough made of Manitoba flour gets softer with the lapse of time although it softens to a smaller degree than doughs made from other flours. The judgment of the baker,

that Manitoba dough becomes more wiry, has probably to be explained by the fact that it does not get softer in the same degree as the baker would expect from his experience of other flours. It is a judgment due to what is known as physiological contrast but the practical result can only be regarded as hallucination.

3. Reliability of the Subjective Judgments about the Properties of Various Doughs

I proposed to carry out two categories of experiments to get a judgment concerning the subjective reliability of the baker. One can try to find out how far the same baker is constant in his judgments concerning the same doughs at different times, and on the other hand how far different bakers agree with reference to the same dough. The first experiment could not easily be carried out at the St. Albans laboratories because it was difficult to conceal from the baker the nature of the samples used in the experiments. In experiments of this kind with baker C the agreement of the judgment concerning the same dough at different times was rather satisfactory. The second experiment was made with five bakers. Baker 1 was S; bakers 2 and 5 are the test bakers for two large mills; baker 3 is the test baker of another mill and he is said to be exceptionally good; baker 4 is a small commercial baker. Four samples of flour were given to each of the bakers, namely, (*a*) English, (*b*) Australian, (*c*) a London + 1/-grade, (*d*) Manitoba. The number of gallons of water to be added per sack was prescribed. The same amount of yeast, salt, malt extract (0.1%), and ammonium phosphate (0.05%) were added in all cases. The statements made by the bakers referred partly to the impressions they got in making the doughs and partly to the experiences obtained during the gassing processes, the knocking back, and the baking processes. I restrict myself to the statements made during the dough-making period of one of the four doughs. The statements made concerning the same doughs differ more than I expected. I cite some of the judgments: Dough *a*. Baker 1: Good bodied dough, good extensibility, fairly good spring. Baker 2: A lively, wiry dough, but slightly sticky at first knock back. Baker 4: Takes water badly, making a poor thin dough of fair ductility but poor resilience. Baker 5: Decidedly weak and dough slightly soft. Even if one takes into account that the various bakers have probably paid attention to different properties of the dough, we cannot overlook the fact that even in some important points the agreement is not satisfactory. Whereas, *e.g.*, baker 1 speaks of good bodied dough and fairly good spring, baker 3, who too is praised as test baker, speaks of a weak flour. Baker 1's opinion might be applicable to a No. 1 Manitoba dough; baker 2's to, say, a No. 3 or 4

Manitoba; baker 5 might, from his description, be dealing with a good sample of Yeoman English, and baker 4 with a poor English flour suitable only for biscuit making. Four experienced test bakers gave opinions of virtually the same dough which differed as widely as No. 1 Manitoba and poor biscuit English! The flour actually was a really excellent sample of ordinary mixed non-Yeoman English. These and other differences in judgment are very likely to be explained by the fact that the bakers in testing the doughs are guided by different principles of judging. We will by no means contest the value of an experienced baker's subjective judgments but obviously there exist certain limits of the reliability of these judgments.

It is possible that by training different bakers along the same lines their judgments could be brought to a better agreement but as long as such a training is not carried out we cannot acknowledge that the subjective judgments prove of high scientific reliability. And we may already at this point mention a statement which will be fully confirmed by the next paragraph—that in differences of opinion between the mills and the bakers, if the bakers can only produce statements of their subjective impressions we are bound to rely more on the statements of the testing laboratory which are based on physical methods of measurement.

4. Comparison between Subjective and Objective Methods in Testing Properties of Doughs

To get an idea of the sensitivity of the feel of the hand compared with the sensitivity of the physical apparatus used for testing the properties of dough, we carried out the following experiments. A series of doughs was made from flours made of mixtures of varying quantities of Manitoba and good non-Yeoman English. (The amount of water added in making the doughs corresponded to the ratio of the two kinds of flour used in the mixture.) We tried to answer the question how much flour of one kind has to be added to the other flour in order for the baker to just appreciate the change in dough properties which took place. In short we tried to establish the psycho-physical threshold in this case. The sensitivity of bakers S and C in these experiments was much lower than we expected: as much as 30% of Manitoba had to be added to the English to make the new dough just distinguishable from the pure English. Similar results were obtained with three German bakers in Germany using the same mixture. We come to the conclusion from these experiments that the physiological sensitivity to such changes in grist cannot be said to be very pronounced. By means of physical methods much smaller additions of Manitoba to English could be detected.

Although considering the above mentioned findings we come to the conclusion that the sensitivity of the human hand for elasticity and viscosity is not very great, we got quite different results in studying the sensitivity of the human hand for stickiness of doughs. I shall describe one of our experiments: We made a dough of Manitoba adding the normal quantity of water. This dough was divided in two halves of the same weight. Then enough water was added to one of the two halves so that its stickiness could just be felt to be different from the stickiness of the other half dough. The amount of water required was about 1–2%, *i.e.*, between $\frac{1}{4}$ and $\frac{1}{2}$ gallon per sack. Again, similar results were obtained with the three German bakers. After this experiment we understood perfectly the great sensitivity of the baker to stickiness and we understand why he pays so much attention to this property. What he really does in making doughs is to produce a minimum of stickiness, and it would seem that our ideal flour would combine a minimum of stickiness in the dough with a maximum of water absorption and of those properties which seem to guarantee an optimum in the bread turned out.

This is in agreement with the conclusion of Halton and Scott Blair that with the majority of flours it is possible that the relationships between stickiness and water absorption on the one hand, and the other physical properties of the dough on the other, are such that when doughs have the required minimum degree of stickiness their other properties are also in a condition for giving satisfaction in the bakehouse.

Note on Experiments with German Bakers

Three bakers took part in the experiments which I carried out in Germany. They were commercial bakers of good intelligence, one was at the same time teacher at a college for bakery and was particularly interested in an investigation of this sort.

Regarding the content of gluten, the German bakers distinguished two properties of flour which they called "griffig" and the contrary "klumpig" (griffig perhaps may be translated by "easy to grasp or handle," klumpig by "lumpy"). Within the property "griffig" the bakers distinguish three degrees:

Doughs of high content of gluten are called "wollig" (= woolly), *i.e.*, they feel like wool. Doughs of small content of gluten are called "kurz" (= short) and "bruechig" (= brittle). In this respect the German bakers use similar expressions as the English ones ("short" and "brittle"). The expressions "good body" and "poor body" are not used by German bakers, but one of them thought body was a good expression for the description of doughs.

When I presented to the bakers a Manitoba and an English dough the differences were described in much the same way as by English bakers. The German bakers were especially delighted by the Manitoba, one of them called the Manitoba the dough which they are "longing for," because of its strong content of gluten.

When I examined the sensitivity of the German bakers I found much the same results as in this country. About 25% to 30% of Manitoba had to be added to the English to make the mixture just distinguishable from pure English. About 2% of water or about ½ gallon per sack had to be added to the English dough of normal water content to make its stickiness just become different from the former dough.

The German bakers are in full agreement with the English ones in that they dislike sticky doughs.

Perhaps I should mention that the German bakers have on the whole less experience with doughs of pure wheat flour and that they are much more used to doughs made of rye. Dough made of rye flour feels of course quite different from that made of wheat flour.

Summary

An attempt is made to analyse the exact meanings of the terms used by bakers in describing dough properties.

These terms are used to express judgments about doughs and those judgments must be analysed psychologically; *e.g.*, which sense-impressions are the basis of these judgments and how do the various sense co-operate? The sense-impressions discussed are those of vision, hearing, temperature, sense organs of skin, muscles, sinews, and joints. Memory plays an important part in the formation of judgments based on sense impressions; thus, in addition to the actual sense impressions obtained in handling doughs, innumerable earlier experiences of similar or other doughs come into play and contribute to the final judgments. These earlier experiences often act as prejudices.

The psychological properties, *e.g.*, body, spring, or elasticity, *etc.*, do not correspond to the physical properties of viscosity, elasticity, *etc.*, but are the result of a complicated co-operation of the different senses of the skin, muscles, sinews, joints, *etc.* Thus, the property called elasticity or spring by the baker does not correspond to the physical elasticity but is more accurately expressed by the viscosity/elasticity ratio.

Subjective impressions compare unfavourably in sensitivity with objective methods of testing dough properties; *e.g.*, addition of 30% of Manitoba flour to English was only just detectable in the dough by the baker.

The reliability of a baker's subjective judgments concerning dough properties is not great. *E.g.*, the judgments of the same baker concerning the same dough made at different times showed good agreement, but the judgments of several bakers on the same dough often show wide differences.

A baker may not be very successful in distinguishing various doughs whose differences, *e.g.*, of elasticity and viscosity, can be defined in an objective way.

This investigation is concerned only with the analysis of the methods by which the baker arrives at a judgment of his dough, of the terms which he uses in describing it, and the reliability of his judgments. Methods of minimising the human factor in dough manipulation have been described by other workers and are not dealt with here.

Acknowledgment

The author desires to acknowledge the collaboration of Drs. E. A. Fisher and P. Halton of the Research Association of British Flour-Millers, and of Miss M. Chadwick of the Food Department, College of Technology, Manchester.

AMINO ACIDS IN STAPLE FOODS. II. THE EFFECT OF MILLING WHEAT ON THE DISTRIBUTION OF AMINO ACIDS

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The customary method of estimating the protein content of wheat flour is to multiply the percentage of nitrogen by the factor 5.7. The result so obtained serves to differentiate between low and high protein flour, but it does not give any information in regard to the nutritional quality of the protein. Since certain amino acids are nutritionally indispensable, not only should the quantity of protein in a food or feed be considered, but also the question whether all of those amino acids which the animal organism is unable to synthesize are furnished in sufficient quantities. That is the reason the author undertook the present study, an inquiry to which no answer in the literature can be found,—What are the changes in the amino acid distribution when patent flour instead of whole wheat flour is milled?

The amino acids considered in this study have been found to be present in both patent and whole wheat flour with only slight variations in quantity. The differences, however, may prove to be more significant when we learn the minimum requirements of these amino acids for the animal organism. Naturally, there are other factors in addition to amino acid content, such as mineral content, vitamins, roughage, and keeping quality, which are important and must be considered in estimating the relative value of patent and whole wheat flours as staple foods.

Experimental and Discussion

In the first article of this series [1] the analytical procedures were described in detail. The flours here used were made from the same samples of Marquis and Tenmarq wheat that had been milled by the Bureau of Agricultural Economics, Department of Agriculture, for use in the previous study. A sample of 20 to 25 g. of material was found to be ample for the cystine and basic amino acid determinations, instead of the 40 g. previously used.

[1] Csonka, F. A. Amino acids in staple foods. I. Wheat (*Triticum vulgare*). J. Biol. Chem. **118**: 147–153 (1937).

For the sake of comparison, the figures on whole wheat flour in Table I are reproduced from the previous publication. It is shown that in milling a 74% patent flour a reduction of proteins occurs as judged by the lower percentage of nitrogen. The loss is caused by the removal of shorts and bran, both of which are higher in nitrogen than the patent flour itself (see Table II).

Although the protein content of the patent flour is lower than that of the whole wheat flour there is an increased percentage of cystine and tryptophane in the patent flour. Wheat protein compares favorably with casein except for the rather low tryptophane content, and this is one of the indispensable amino acids found in increased amount in the patent flour. The dibasic amino acids and tyrosine are found in higher percentages in the whole wheat flour.

To be able to trace these differences in the amino acid distribution caused by the milling process, the shorts and bran removed in the preparation of patent flour from Tenmarq wheat were collected separately and analyzed for their several amino acids.

It is noteworthy that in the proteins of shorts (which contains the embryonal tissue, high in lysine, arginine, and tyrosine), the percentages of these amino acids are approximately double those found in patent flour, which consists almost entirely of the endosperm. Jones and Gersdorff [2] analyzed purified protein preparations from wheat bran and found in general higher percentages of the dibasic amino acids than were present in the corresponding proteins of the endosperm. Their finding in regard to lysine is substantiated by these results (see Table II). Since both shorts and bran are used in commercial feed mixtures, they are not to be considered wastes in the manufacture of patent flour, but rather, valuable by-products.

TABLE I

THE AMINO ACID AND NITROGEN PERCENTAGES IN MOISTURE-FREE WHOLE WHEAT AND PATENT FLOURS

	Marquis Hard Spring		Tenmarq Hard Winter	
	Whole wheat flour	Patent flour	Whole wheat flour	Patent flour
	%	%	%	%
Amino Acids				
Cystine	0.27	0.31	0.17	0.23
Tryptophane	0.09	0.12	0.07	0.09
Tyrosine	0.87	0.48	0.56	0.49
Arginine	0.51	0.41	0.38	0.33
Histidine	0.28	0.18	0.12	0.11
Lysine	1.51	0.99	1.23	0.86
Total nitrogen	3.31	3.02	2.58	2.13

[2] Jones, D. Breese, and Gersdorff, Chas. E. F. Proteins of wheat bran. II. Distribution of nitrogen, percentages of amino acids and of free amino nitrogen: A comparison of the bran proteins with the corresponding proteins of wheat endosperm and embryo. J. Biol. Chem. 64: 241–251 (1925).

TABLE II

THE AMINO ACID AND NITROGEN PERCENTAGES IN MOISTURE-FREE BRAN AND SHORTS OBTAINED BY MILLING 74% PATENT FLOUR FROM TENMARQ HARD WINTER WHEAT

	Cystine	Trypto-phane	Tyrosine	Arginine	Histidine	Lysine	Total nitrogen
	%	%	%	%	%	%	%
Bran.....	0.09	0.05	0.83	0.33	0.052	1.85	2.75
Shorts.....	0.13	0.07	0.88	0.69	0.050	2.00	3.22

Knowing the amino acid compositions of the individual milling fractions, one may calculate these constituents for the original whole wheat flour. Table III illustrates the distribution of amino acids in

TABLE III

THE CALCULATED AMINO ACID DISTRIBUTION IN THE COMPONENTS OF WHOLE WHEAT FLOUR, BASED ON SEPARATIONS OBTAINED BY MILLING 74% PATENT FLOUR FROM TENMARQ HARD WINTER WHEAT

	Cystine	Trypto-phane	Tyrosine	Arginine	Histidine	Lysine	Total nitrogen
	%	%	%	%	%	%	%
74% Patent...	0.17	0.067	0.36	0.244	0.081	0.636	1.6
13.2% Shorts..	0.02	0.009	0.12	0.091	0.007	0.264	0.5
12.8% Bran...	0.01	0.006	0.11	0.042	0.007	0.237	0.4

the whole wheat flour, as divided among the milling products when patent flour is manufactured, the values being calculated from the analytical data for each component. The color produced in the tryptophane determination of the patent flour was excellent, but matching the tryptophane test solution of bran, which had a greenish tint, with the casein standard was rather difficult. Although the shorts also produced a slight greenish color, a fair reading was obtained, and by using this solution as a standard for the bran a more satisfactory match resulted. The reliability of this technique may be judged from the data for tryptophane given in Table III.

It would be very interesting to follow up the effect on the amino acid distribution produced by manufacturing processes such as bleaching, yeast fermentation, and baking, as actually applied in the cereal and baking industries, each being a protein nutritional problem of far-reaching importance.

Summary

Patent flour and whole wheat flour milled from the same samples of wheat were analyzed for their amino acid compositions. Cystine and tryptophane were higher in patent flour, while tyrosine and the dibasic amino acids were higher in whole wheat flour. The amino acid contents of the two by-products, shorts and bran, were also determined.

VARIABILITY IN CAROTENOID PIGMENT CONTENT OF INDIVIDUAL PLANTS OF TRITICUM VULGARE AND TRITICUM DURUM [1]

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The pigmentation of wheat is of considerable commercial importance and accordingly has been the subject of numerous investigations. For the purpose of bread, cake, and pastry production an endosperm color of white or pale yellow without appreciable quantities of grays or browns is most desirable. The milling methods now in use are efficient enough to make bran color a secondary consideration. In the production of macaroni and similar products a deep clear yellow color of the endosperm is most highly desirable. Since, in the production of the coarse semolinas used in macaroni manufacture, it is impossible to remove all bran fragments, the bran must be as near the same color as the endosperm as possible. Accordingly, better semolinas can be produced from amber durums than from red durums.

The principal pigments of the wheat endosperm have been shown to be carotenoid in nature. Markley and Bailey (1935a) found xanthophyll to be the principal pigment with carotene present in minor quantities. Several as yet unidentified pigments were also present in the gasoline extract. A precise method for determining the carotenoid pigment concentration of wheat flour was developed by Ferrari and Bailey (1929) and later slightly modified by Ferrari (1933). Whiteside (1931) adapted the method of Ferrari and Bailey to finely ground whole wheat meal. He found a very high correlation between the carotenoid content of the patent flour and that of the finely ground whole wheat meal. This method was modified by Markley and Bailey (1935b) so as to be used upon samples as small as 0.55 g. of whole wheat. The coefficient of variability of replicated determinations upon aliquots of a single lot of wheat was found to be 8.5.

A knowledge of the mode of inheritance of the pigments would be highly desirable since much of the work in breeding disease-resistant types has involved the use of parent material which was decidedly

[1] Paper No. 1455, Journal Series, Minnesota Agricultural Experiment Station. Condensed from a thesis presented to the Graduate School of the University of Minnesota by Max C. Markley in partial fulfilment of the requirements for the degree of Doctor of Philosophy, June 1934.

TABLE I

STATISTICAL CONSTANTS FOR KERNEL WEIGHTS AND CAROTENOID CONCENTRATIONS OF THE DIFFERENT SERIES OF WHEAT PLANTS USED IN THIS STUDY

Group	Number of samples	A. Kernel weight			B. Carotenoids, p.p.m.		
		Mean mg. S. E.	S. D.	C. V.	Mean S. E.	S. D.	C. V.
				%	p.p.m.		%
Minnesota No. 2303 Plot 878 (1931)	72	26.3889 ± .4773	4.0502	15.3482	2.4471 ± .0489	.4152	16.9668
H-44 Plot 881 (1931)	28	26.0000 ± 1.4097	7.4594	28.6901	2.9014 ± .1384	.7322	25.2360
H-44 Plot 881 (1932)	51	29.1176 ± .6460	4.6131	15.8428	2.0961 ± .0408	.2912	13.8923
I-00-52 (1933)	46	30.1087 ± 1.3646	9.2554	30.7399	3.5726 ± .1357	.9204	25.7619
II-19-116 (1933)	33	32.2727 ± 1.7826	10.2404	31.7307	3.0279 ± .1502	.8627	28.4903
II-19-116 × I-00-52 F2 (1933)	48	33.7083 ± 1.3850	9.5959	28.4675	3.0425 ± .1507	1.0443	34.3232
I-00-52 × II-19-116 F2 (1933)	96	34.3542 ± .9256	9.0691	26.3990	3.2540 ± .1007	.9862	30.3083
II-19-149 (1932)	23	35.6597 ± 1.1706	5.6139	15.7272	2.9861 ± .0800	.3837	12.8506
I-00-52 (1932)	14	32.2857 ± 2.3526	8.8028	27.2654	3.7400 ± .1546	.5783	15.4632
II-19-149 × I-00-52 F2 (1932)	30	35.5667 ± 1.4124	7.7360	21.7507	3.5787 ± .1528	.8368	23.3844
I-00-52 (1933)	31	34.2903 ± 1.6316	9.0845	26.4930	2.7271 ± .1052	.5857	21.4766
II-19-149 (1933)	27	30.5926 ± 1.0065	5.2300	17.0955	2.4363 ± .0768	.3990	16.3759
I-00-52 × II-19-149 F2 (1933)	79	32.6076 ± .9802	8.7125	26.7192	2.7618 ± .0623	.5541	20.0636

Group	C. Carotenoids per kernel			D. Carotenoids per kernel (Cor.)			Correlations	
	Mean mg. × 10^{-6} S. E.	S. D.	C. V.	Mean mg. × 10^{-6} S. E.	S. D.	C. V.	r_{AB}	r_{AC}
			%			%		
Minnesota No. 2303 Plot 878 (1931)	63.5278 ± .9921	8.4179	13.2507	69.0417 ± .8283	7.0286	10.1802	−.7232 ± .0562	+.5541 ± .0817
H-44 Plot 881 (1931)	70.4286 ± 2.4502	12.9654	18.4093	76.4643 ± 1.3107	6.9358	9.0707	−.8595 ± .0495	+.8386 ± .0563
H-44 Plot 881 (1932)	60.3529 ± 1.1960	8.5411	14.1519	61.7843 ± .8717	6.2255	10.0761	−.5396 ± .0992	+.7066 ± .0700
I-00-52 (1933)	101.5217 ± 3.1213	21.1698	20.8525	125.2174 ± 2.8855	19.5703	15.6290	−.7104 ± .0731	+.9567 ± .0124
II-19-116 (1933)	94.6970 ± 5.9621	34.2500	36.1679	113.1515 ± 4.7760	27.4360	24.2471	−.3493 ± .1529	+.6047 ± .1104
II-19-116 × I-00-52 F2 (1933)	95.9167 ± 3.2153	22.2765	23.2249	111.3958 ± 3.4483	23.8902	21.4462	−.6670 ± .0801	+.4322 ± .1174
I-00-52 × II-19-116 F2 (1933)	106.7716 ± 3.3253	32.5811	30.5148	119.8125 ± 3.2462	31.8058	26.5463	−.5663 ± .0694	+.3688 ± .0882
II-19-149 (1932)	106.3478 ± 4.4909	21.5378	20.2522	116.6522 ± 3.0862	14.8401	12.7217	−.1013 ± .2064	+.7337 ± .0962
I-00-52 (1932)	118.1429 ± 7.7760	29.0955	24.6274	136.6429 ± 3.7966	14.2056	10.3962	−.5351 ± .1908	+.8881 ± .0565
II-19-149 × I-00-52 F2 (1932)	123.5000 ± 5.2349	28.6726	23.2166	134.1667 ± 3.9694	21.7410	16.2045	−.3869 ± .1552	+.6037 ± .1162
I-00-52 (1933)	90.1290 ± 3.6583	20.3688	22.5996	103.8710 ± 2.5160	14.0086	13.4865	−.6508 ± .1035	+.8456 ± .0511
II-19-149 (1933)	74.1852 ± 3.1396	16.3141	21.9911	96.7037 ± 2.4359	12.6573	13.0888	−.2283 ± .1824	+.6407 ± .1134
I-00-52 × II-19-149 F2 (1933)	89.1900 ± 2.9074	25.8413	28.9734	106.8987 ± 1.7296	15.3727	14.3806	−.2045 ± .1078	+.8049 ± .0398

inferior in this respect with the result that many, and in some crosses all, of the disease-resistant lines had to be discarded because of unacceptable endosperm coloring. Clark and Smith (1928) found an indication of transgressive inheritance in carotenoid pigment content in durum wheat crosses.

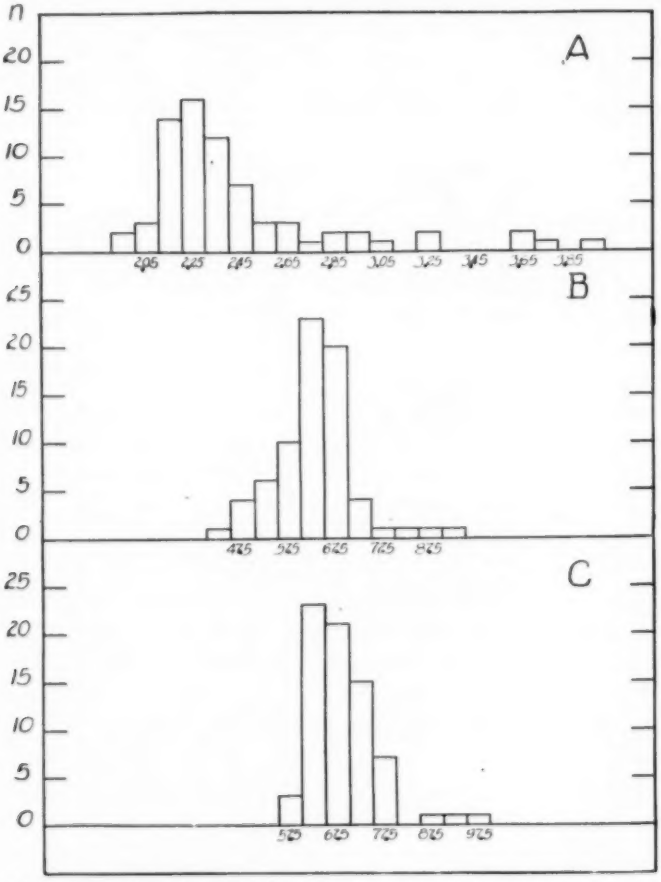

Figure 1. Distribution of individual plants of Minnesota No. 2303 wheat according to carotenoid content.

A. Carotenoids as parts per million.
B. Carotenoids as mg. $\times 10^{-4}$ per kernel.
C. Carotenoids as mg. $\times 10^{-4}$ per kernel, corrected.

The first portion of the work was to determine the variability existing between individual wheat plants of apparently the same genotype. For the purpose of determining this value individual plants of 2 varieties of hard red spring wheat, Minnesota No. 2303 and H-44, were grown in small plots in the nursery at University Farm, St. Paul, Minnesota, in 1930. There was some damage by root rot

organisms causing a rather high variability in kernel weight, as is shown in Table I.

Determination of carotenoid content was made upon 72 plants of Minnesota No. 2303 and upon 28 plants of H-44 wheat during the

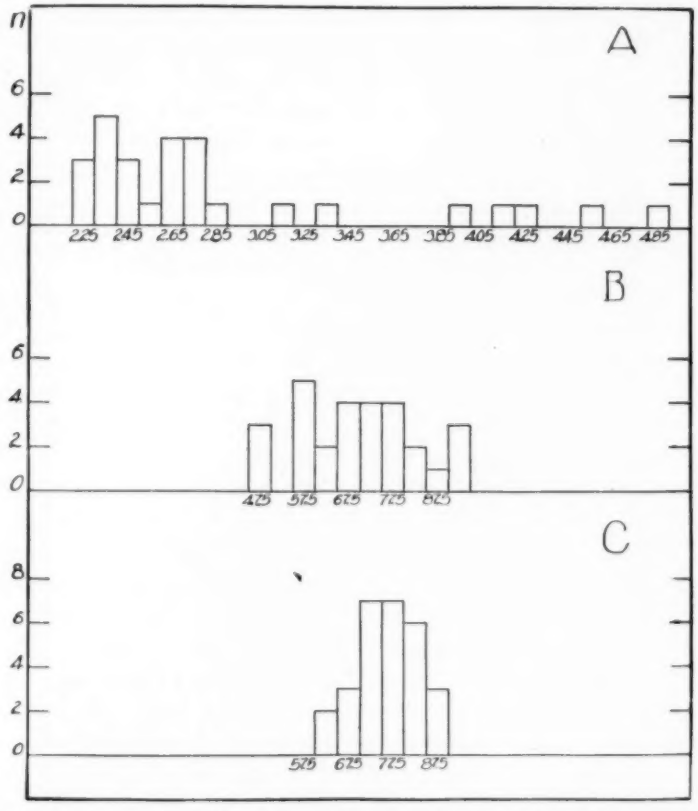

Figure 2. Distribution of individual plants of H-44 wheat (1931) according to carotenoid content.

A. Carotenoids as parts per million.
B. Carotenoids as mg. $\times 10^{-6}$ per kernel.
C. Carotenoids as mg. $\times 10^{-6}$ per kernel, corrected.

summer of 1931, while 51 samples of the H-44 were not analysed until the succeeding summer. Due to storage loss of pigment the two sets of data upon the H-44 wheat could not be combined, but had to be considered separately. When the carotenoid pigments were calculated as parts per million of the ground wheat meal the coefficient of variation for the No. 2303 wheat was 17.0 and the distribution, as shown in Figure 1, decidedly skewed. The two lots of H-44 wheat were found to be similar to the No. 2303, as can be seen by an inspection of Table I, and Figures 2 and 3.

A correlation of $r = -.72$ was found between kernel weight and carotenoids as parts per million in the case of the No. 2303 wheat. In the cases of the two lots of H-44 wheat the correlations were similar. In view of these negative correlations the carotenoid pigment concentrations were recalculated to the basis of quantity of pigment per

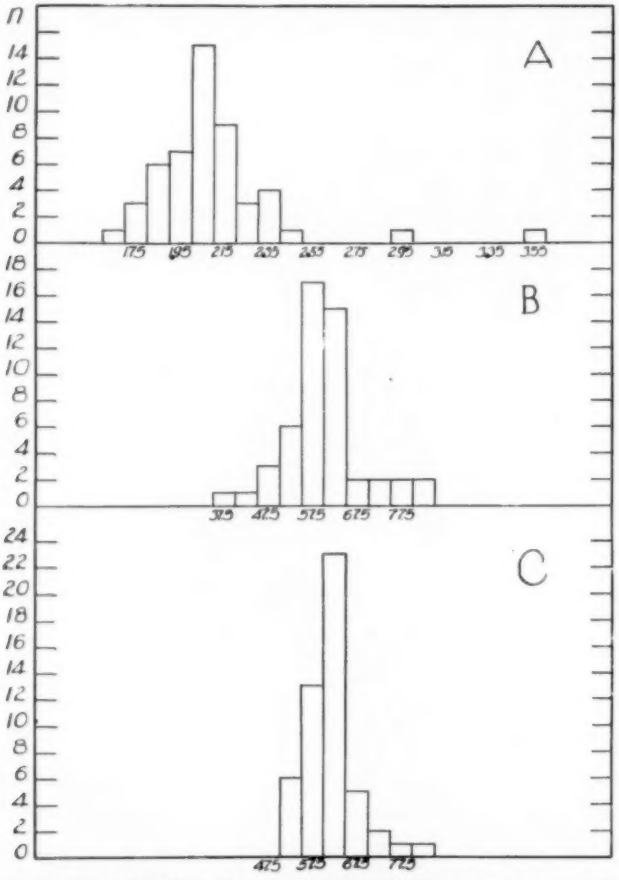

Figure 3. Distribution of individual plants of H-44 wheat (1932) according to carotenoid content.

A. Carotenoids as parts per million.
B. Carotenoids as mg. $\times 10^{-6}$ per kernel.
C. Carotenoids as mg. $\times 10^{-6}$ per kernel, corrected.

kernel. The mean results are given in Table I. The variability was appreciably reduced in two cases by this calculation, but was slightly increased in the 1932 H-44 series. The distributions were no longer skewed and did not have the extreme spread of the parts per million method. The correlation between kernel weight and carotenoids per kernel was positive now instead of negative as in the previous calculation, being $r = .55$ for the No. 2303 wheat, and $r = .84$ and $r = .71$

for the two lots of H-44 wheat. This relationship was also found to hold throughout a number of durum wheat series which were later studied. The correlation between kernel weight and carotenoids per kernel was found to be correlated to the extent of $r = .5557 \pm .2303$ with the coefficient of variability in kernel weight.

By a study of the trends of the regression coefficients between kernel weight and carotenoids per kernel, it was found that at a theoretically perfect correlation the regression coefficient would be approximately 1.5 for the three vulgare series. This indicates that for 1 mg. increase in kernel weight there is to be expected an increase of 1.5×10^{-6} mg. of carotenoid pigments.

The method of applying this factor was to arbitrarily take a standard kernel weight and correct all the others to it. The weight so chosen is the weight of average normal plump seed, which, for these vulgare lines, was taken to be 30 mg. The method of correction is shown by the following example: Plant 878–97 had kernel weight of 20 mg. and carotenoid content of 50×10^{-6} mg. Applying the correction factor we have to add 15×10^{-6} mg. to the carotenoid figure to compensate for the 10 mg. deficiency in kernel weight. For kernel weights over the standard weight the process is reversed.

When these corrections had been applied to the three vulgare series the variability between plants was still further reduced, until it was only from 0.5 to 1.5% above the variability of the method itself. This is shown in Table I, and graphically in Figures 1, 2, and 3.

A number of years before this study was started crosses had been made at the Minnesota Station between the highly-pigmented, leaf-rust-susceptible Mindum durum wheat and the low-pigmented, rust-resistant Pentad variety. Several rust-resistant amber strains were selected and increased, but upon test produced macaroni inferior in color to that of the parent Mindum durum. This study was then undertaken to determine if it were possible to transfer the intense carotenoid pigmentation of the Mindum into a hybrid with the lighter pigmented strains. Reciprocal crosses were made in the summer of 1930 between Mindum (I-00-52) and two of the Mindum × Pentad hybrids (II-19-116 and II-19-149). F-1 generation was raised in the greenhouse that winter. The F-1 plants in each cross were very uniform, indicating that all were probably hybrids and not self pollinated. The F-2 seed was planted in the nursery in the spring of 1931. Self-pollinated seed from each plant used as a parent was also sown in the same section of the nursery. The yield was low and the seed frequently of poor quality due to a combination of drought and root-rot infestations. The seed from each plant was harvested and threshed individually.

The coefficient of variability of carotenoid pigment content, corrected to 40 mg. kernel weight, of the Mindum durum varied from 10.4 to 15.6. Strain II-19-116 was much more variable being 24.2. This strain was very susceptible to root-rot infections, was a little earlier in maturity than the Mindum (I-00-52), and produced very poor seed; several of the parent lines were lost. Strain II-19-149

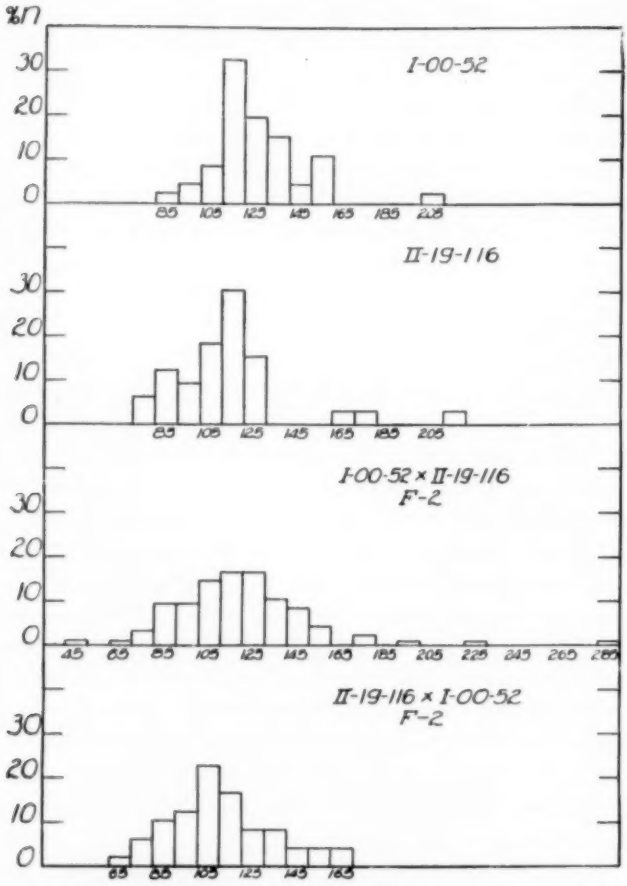

Figure 4. Distribution of individual wheat plants according to carotenoid content as mg. × 10^{-6} per kernel at 40 mg. kernel weight.

was more disease resistant and had less variability in carotenoid content (12.7 and 13.1) than II-19-116 and was about the same as the Mindum. The two hybrid strains averaged about 12 × 10^{-6} mg. of carotenoid pigments less per kernel than the Mindum. The distributions of the individual plants of each series of these strains are shown in Figures 4, 5, and 6.

When the F-2 population was studied for carotenoid content it was found that in all cases there was greater variability in the F-2 than in the Mindum (I-00-52) parent, also than the II-19-149 parent. However, there was about the same variability in the F-2 as in the II-19-116

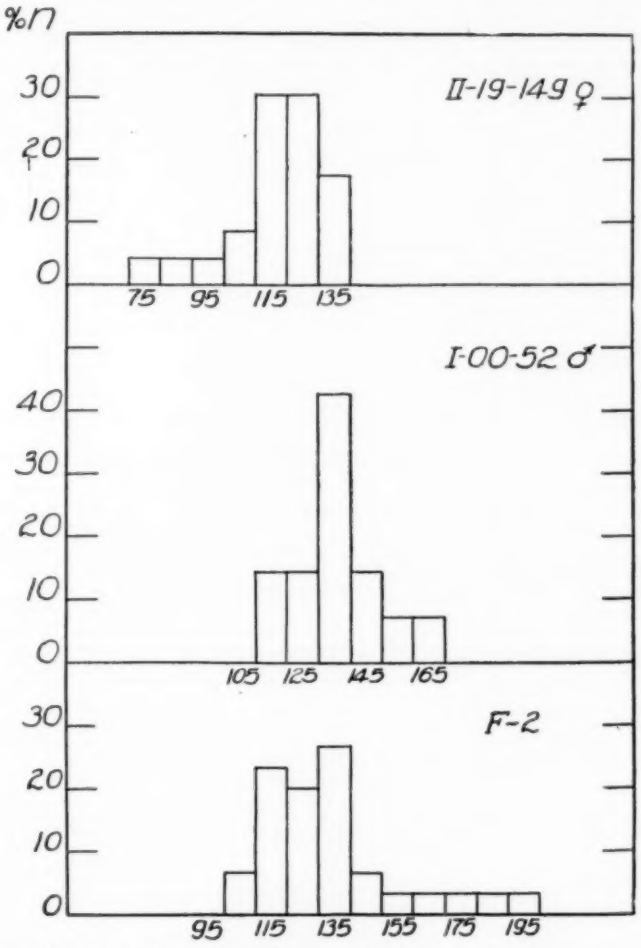

Figure 5. Distribution of individual wheat plants according to carotenoid content as mg. $\times 10^{-4}$ per kernel at 40 mg. kernel weight.

parent. The hybrids tended to be intermediate in the cases of the crosses with II-19-116, but averaged about the same in pigment concentration as the Mindum in the crosses with II-19-149.

These results indicated that it was possible to transfer the pigmentation of the Mindum durum wheat into hybrids with lower pigmented strains. The distributions of the F-2 lines showed no definite segregation ratios, which was as expected when the complex nature of the pigments was considered.

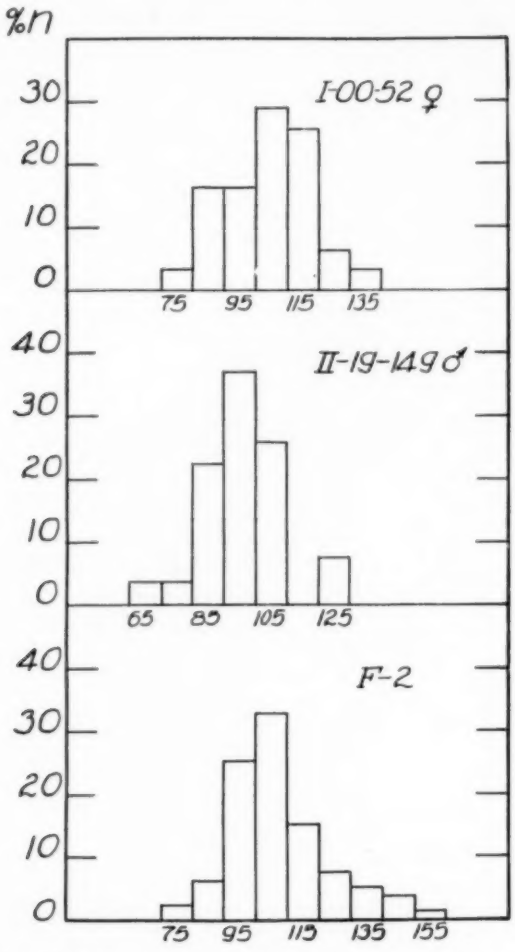

Figure 6. Distribution of individual wheat plants according to carotenoid content as mg. $\times 10^{-6}$ per kernel at 40 mg. kernel weight.

Summary

Total carotenoid content of individual wheat plants when calculated as parts per million of the ground wheat meal was negatively correlated with kernel weight.

Total carotenoid content of individual wheat plants when calculated as weight of pigment per kernel was positively correlated with kernel weight.

Variability in kernel weight was positively correlated with the correlation between kernel weight and weight of carotenoids per kernel.

Correction factor for carotenoid pigments was calculated from the regression of weight per kernel and carotenoids per kernel.

Variability in carotenoid pigments per kernel was reduced nearly to the experimental error by correcting for variations in kernel weight by means of an appropriate correction factor.

Mendelian ratios were not found upon examination of the carotenoid content of individual F-2 plants from crosses between varieties of durum wheat differing in carotenoid content.

Multiple factor inheritance of carotenoid pigments was found in durum wheats.

Highly-pigmented plants were found in the F-2 population of crosses between the highly-pigmented Mindum durum and less highly pigmented Mindum × Pentad lines.

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Literature Cited

Clark, J. A., and R. W. Smith
1928 Inheritance in Nodak and Kahla durum wheat crosses for rust resistance, yield and quality at Dickenson, North Dakota. J. Am. Soc. Agron. **20**: 1297–1304.

Ferrari, C. G.
1933 Spectrophotometric determination of the carotinoid pigment content of wheat flour. Cereal Chem. **10**: 277–287.

—— and C. H. Bailey
1929 The determination of carotin in flour. Cereal Chem. **6**: 347–371.

Markley, M. C., and C. H. Bailey
1935a The nature of the pigments of the gasoline extract of wheat. Cereal Chem. **12**: 33–39.

——
1935b Determination of the carotenoid pigment concentration of small samples of whole wheat. Cereal Chem. **12**: 49–53.

Whiteseide, A. G. O.
1931 A study of the carotinoid pigments of wheat and flour with special reference to wheat varieties. Can. Dept. Agr. Bull. 154, New Series.

REVIEW OF BREWING LITERATURE ISSUED FROM JUNE 1, 1935 TO JUNE 1, 1936, WITH SPECIAL REFERENCE TO BARLEY, MALT, AND MALT ADJUNCTS

ELSIE SINGRUEN

(Read at the Annual Meeting, June, 1936)

In most countries the agronomic problems related to the production of barley for malting purposes have again attracted considerable attention. The unusual weather conditions prevailing during the growing season of the 1935 crop which were responsible for wide variations in barley composition, necessitated a number of special investigations in addition to the usual crop survey reports.

The world production of barley in 1935 was estimated as 1,574,000,000 bushels, excluding China, the United States contributing 292,250,000 bushels. In general, the quality of malting types of barley was below normal and therefore there was a scarcity of top grade barleys for malting purposes.

The development of new varieties of malting barley and the determination of their suitability for brewing purposes as judged by experimental maltings has assumed particular importance in the United States since the repeal of the Eighteenth Amendment. The first report on the coordinated research program sponsored by the Barley Improvement Council and carried out at the University of Wisconsin by means of experimental malting equipment, was presented by Prof. J. G. Dickson and his collaborators (1935) at the Denver meeting of the American Association of Cereal Chemists.

The educational activities of the Barley Council, concerned with the selection of proper seed barley for the farmer, were discussed in an address before the Cincinnati Section of the Master Brewers' Association of America by Prof. E. D. Holden (1936) of the University of Wisconsin who, for his outstanding work in this field, received the first Annual Achievement Award inaugurated by the Master Brewers of this district.

The experimental malting equipment of the University of Minnesota, which is particularly intended for the study of biochemical changes during the malting process, was described by J. A. Shellenberger and C. H. Bailey (1936). A previous publication of the same authors dealt with the imbibition rates of commercial malting barleys during steeping.

A detailed description accompanied by illustrations of the experi-

mental malting plant in the United States Department of Agriculture at Washington, D. C., was given by Coleman (1936). This unit is operated in connection with the Department's grain standardization investigations.

Comprehensive information on the Canadian barley situation was presented by Anderson (1936) who reported on the educational and research work organized under the National Barley Committee in collaboration with the Malting Laboratory of the University of Manitoba. Also, in this connection, should be mentioned the Official Report of this Committee, which contains "information on the classification and grading of barleys, their uses; instructions on the selection of seed, its treatment; the time of sowing and reaping and the precautions necessary during threshing to obtain highest grade of malting barley." The Second Annual Survey of Protein Content of Western Canadian Barleys by Geddes and Eva (1935) is also informative.

Bishop (1935), of the British School of Malting and Brewing in Birmingham, pointed out the varietal differences in British malting barley strains and how these differences can be applied in assessing the relative merits of old and new barley varieties. His paper included a description of the characteristics of varieties, and names the barleys best suitable for the production of various types of beer. In another paper the same author (Bishop, 1936) discussed the effect of variety, soil, and season on the barleys and malts of the 1932 and 1933 crops. Additional British crop reports relative to barleys of the 1935 season were published by Clarke (1935) and Thorpe (1935). Thorpe's investigation included as well malting barleys from all parts of the world.

According to Nilsson-Ehle (1935), of Sweden, the deriviation of new barley varieties in the Scandinavian countries is effected either by selection of pure strains from mixtures or by hybridization.

Of particular interest are the crop reports from Germany and other Central European countries in which unfavorable climatic conditions prevailed,—a long cold spring, followed by hot weather and drought. The effect of drought varied with the variety of barley and with soil conditions. Compared with normal years, the color was exceptionally light, moisture abnormally low and the protein content high. Low yields and high viscosity values were characteristic of the 1935 crop. The quality of these barleys and their modification were not always satisfactory. The kernel formation was affected, as indicated, by assortments distinctly different from normal years, also the husk was found coarser in many instances. Austrian and Hungarian crop reports with similar results were presented by Heinisch (1936).

A new type of damage to barley kernels was reported by Leopold and Horak (1935). Due to rapid changes in humidity and temperature, either in the field or during improper storage and drying, the husk in the ventral furrow cracks and the exposed endosperm is decomposed by the enzymatic activity of certain molds whereby germination capacity and diastatic power are reduced to a minimum.

A comprehensive study of Swedish (two-rowed) brewing barleys grown during the crop years 1926–1934, dealing particularly with varietal properties, was presented by Thunaeus and Schroederheim (1935). The ratio of the total *N* content of the wort (Congress method) to the total *N* of the malt, was found to be a distinct varietal property which was affected very little by the modification of the malt. The difference between the extract content of steeped barley and that of the malt changes with the variety, while the ratio of the individual *N* fractions to total soluble *N* in the wort is only slightly influenced by this factor. The diastatic power also is a varietal property, while catalase content is not.

Ivanov (1935) compiled data on the chemical characteristics of malting barleys from the Soviet Union.

The study of the suitability of huskless barleys for brewing purposes was continued through the past year, especially in Eastern Central Europe. According to Hess and Maerzinger (1936) quality beer can be produced from these barleys assuming that correct malting and brewing procedures are employed.

Almendinger (1936) provided analytical data on 109 huskless barleys of the 1934 crop, representing 13 different two-row varieties. With such barleys the ratio of protein to starch is closer than for ordinary barleys, although the sum of protein plus starch is practically the same for all varieties.

Several contributions have likewise been made to our knowledge of barley diseases and the resistance of varieties (Tapke, 1935; Newton and Johnson, 1936; and Johnston and Aamodt, 1935).

Evaluation of Barley

Barley evaluation has again occupied a prominent place in barley investigations. That there is considerable difference in the manner of evaluating in various countries is evident from the types of scoring systems as well as from the values given to various scoring points. Heinisch (1936) discussed the evaluation schemes used for Austrian and Hungarian barleys pointing out the considerable difference in the scoring system and the relative values given to various scoring points.

Bishop (1936a) proposed a new scheme for evaluating the brewing value of barley in which (1) the potential yield of extract, the soluble

N in the barley, and (2) the actual yield of extract and soluble *N*, color, flavor, and modification in malt are the essential factors.

Petit (1935), however, questioned the validity of relating degree of modification to percent of soluble *N* since it assumes a relationship between growth of plumule and soluble *N* which he has found to be affected by factors other than modification, such as temperature and germination.

Extract Determination

A new method for determining the extract in barley was suggested by Lüers and Von Miller (1935). The modification of the barley starch is effected by means of a highly active starch liquefying enzyme —*super-clastase*—derived from bacteria. For subsequent saccharification, Mark's standard diastase is used. Current methods for extract determination in barley, *i.e.*, those of Graf, Pawlowski, Rottenbach-Schultze and Lüers-Miller were reviewed by Siegfried (1936). The highest values were obtained with the Lüers-Miller (1935) method and the lowest with Graf's method. As the former method is simple and quick in execution, it is recommended by the author as a standard method.

Several suggestions have been published with regard to the determination of nitrogen in barleys, such as new types of apparatus and the use of a selenium-mercury catalyst. A combination of moisture and *N* determination on the same sample has been described.

Malting

One of the outstanding papers of the past year was Lüer's (1935) review of the development of enzymes during malting. Included in this article is a discussion of carbohydrases, proteases, esterases, phosphatases, and desmolases. The total enzymatic activities in germinating barley are manifest to a certain extent by the amount of cold water soluble extract, while an increase in soluble *N* is a criterion of protein degradation. The increase in soluble *N* is considered a criterion for total proteolysis. The interdependence of proteolytic and amylolytic function was pointed out.

In order to gain information on the oxidation-redution reactions (respiration) during germination, Fink, Haehn, and Zenger (1936) investigated the dehydrases, as well as their distribution in the kernel, by means of the modified Thunberg-Ahlgreen methylene blue method (see bibliography). The development of dehydrases during germination was found by them to depend upon the variety and on the malting procedure. The embryo is richest in dehydrases, followed closely by the acrospire. The mealy body, (endosperm) as well as the roots and husk are practically free from oxidation-reduction enzymes.

The functions and properties of sisto and eleuto-substances and their importance with respect to amylolytic activity in brewing and distilling were defined by Deplanque (1936) in a recent publication.

Protein metabolism during malting and the relation between protein cleavage and enzyme action was followed by Kolbach (1935) through the various stages of the malting process, by determining the permanently soluble nitrogen. Schild (1935) suggested the application of existing colorimetric methods for the quantitative determination of individual amino-acids to malt worts in order to separate the formol-titratable *N* from the amino-acid nitrogen and thus study the activity of the peptidases.

Interesting work on the fractionation of barley and malt proteins was reported by Rose and Anderson (1936). The protein content of the Canadian variety of O.A.C. barley and of the malt produced from it was fractionated and the fractions analyzed. Methods were described for the extraction, hydrolysis and *N* determination, also for the determination of the physical fractions of the kernel. The distribution of the *N* fractions in various parts of the kernel was also studied.

Myrbäck, of Stockholm, (1935) regards the difference between water soluble and papain soluble diastase during germination as a measure of modification. The relationship between the diastatic power of respective varieties was found to remain approximately the same from year to year.

Chabot and deWever (1935), of Ghent, explained the significance of the iso-electric point of barley constituents and their degradation products. A simple method for the determination based on surface tension measurements has been developed.

The steeliness of malt kernels, according to LeCorvaisier (1935) is due to incomplete transformation of the starch. Such kernels contain a relatively high proportion of small, undeveloped starch granules or an excess of nitrogenous substances. Deductions as to the cause were made by means of ash determination, hydrolysis, iodine reaction, gelatinization, and temperature effects.

Waldschmidt-Leitz and Mayer (1935) stated that starch transformation is easily observed by viscosity measurements. De-phosphorilization is proportional to the decrease in viscosity. The investigators proposed an amylo-phosphatase unit based on viscosity decrease.

The Windisch-Kolbach method for determining diastatic power was modified by Deplanque and Lampe (1935) for use with green malts. They also discussed the influence of the protein content on the solubility of amylase and the effect of filtration and activators, such as salt solution, Witte peptone, *etc.*

Great advancements have been made in the standardization of malt analysis as indicated by our committee report (1935) and the issuance of the revised edition of the official methods of the American Society of Brewing Chemists.

Coleman and Snider (1935) as well as Nowak and Enders (1936) have compiled comparative data on current methods of moisture determination.

The increasing number of publications on the modification of malt indicate a trend toward establishing more definite malting characteristics for this factor than are available at the present time. Since the proportion of soluble pentosans in barley increases considerably during the malting process, Fink (1935) suggests that their determination might serve as a useful measure of the degree of modification in the malt. Although there exists an approximate parallelism between degree of modification and soluble pentosan content (in percent of total pentosans), this method like the determination of soluble *N* is only of limited value because of reverse reactions during the later stages of germination.

Hanes (1935) using selective biological fermentation methods, confirmed the assumption that β-amylase selectively hydrolyses only one portion of the starch (60%) which is converted into maltose while α-amylase does not seem to exert a selective action on the erythrogranulose fraction, as is generally assumed, but that it induces the breakdown of both fractions. In this case the reduction products are not pure maltose.

Piratzki (1936) showed conclusively that there exists a direct relationship between viscosity and modification of malt. He provided experimental evidence, however, to show that neither the proteins, dextrins nor the pentosans are responsible for the decrease in viscosity. By distillation methods, he isolated a fat or wax-like substance which perhaps is originally present in a different form (lecithin) in the malt. Viscosity values of 1060 to 1080 (water 1000) are considered as normal for two-rowed (European) malts of satisfactory modification; in the malts of the 1934 and 1935 crops values as high as 1140 were found frequently.

A suggestion of perhaps a more practical nature was advanced by Hartong (1936) in the form of a modification number—a numerical value between 1 and 10 obtained by subtracting 60 from the average extract figures of a malt mashed simultaneously at 25°, 65°, and 85° C. As the result of his investigation, a modification scale for the evaluation of the brewing value of European malts of the following order was set up: 0–3½ poorly modified, 4–4½ normal modification for keg beer, 5 ideal modification; 5½–6 increasing over-modification. For American and English malts the respective zones are higher.

Petit (1935a) enumerates the factors contributing to the color formation during malting with special reference to the effect of the individual parts of the kernel.

A most comprehensive review of existing methods for the determination of color in wort and beer is presented by Enders (1936) who introduces at the same time an "objective" color determination by absorption using the Lange Colorimeter and standard melanoidin absorption curves for comparison.

Lüers and Geiger (1935) studied the hordein content of 33 malts of diverse character. This protein component varied from 21.85 to 34.2% of the total nitrogen depending upon the protein content and the degree of modification. This factor may ultimately serve as another criterion for proteolysis.

According to Kopecky (1935) the absolute and relative surface tension of laboratory malt worts measured with the tensiometer "Cenco-du-Nouy" gives sufficiently reliable values. The surface tension during malting is subjected to constant changes.

Very little has been published on the composition and use of malt adjuncts with the exception of a few articles in French papers. Raux (1935) discussed the merits of starch flours as a malt adjunct and states that in the case of a reduction in the percentage of raw grain, high diastatic malts must be replaced by short grown but well-modified malt with corresponding changes in the brewing process.

Desnoullet (1935) reported further attempts to use barley in various forms, such as in flakes, *etc.*, as a malt adjunct. These products usually produce good foaming capacity, but the resulting beer is not always chill-proof.

Literature Cited

Almendinger, V.
1936 Sboring **11**: 122.
Anderson, J. A.
1936 Canadian barley. J. Inst. Brewing **33**: 35–44.
Beet, A. E., and Furzey, D. G.
1936 A new Kjeldahl method for the determination of nitrogen in foods, feeding stuffs, leather, *etc.* Chemistry and Industry **55**: T108–109.
Bishop, L. R.
1935 Barley varieties for brewing. J. Inst. Brewing **32**: 329–334.
1936 Effect of variety, soil, and season on the barleys and malts of the seasons 1932 and 1933. *Ibid.* **33**: 10–14.
1936*a* New light on malting and brewing. *Ibid.* **33**: 103–118.
Brewers' Bulletin, Vol. 29, No. 14.
1936 World barley production and yield.
Chabot, G., and de Wever, J.
1935 Etudes sur le point isoélectrique. 4th Intern. Tech. Chem. Congress Agr. Ind., Bruxelles (July 1935).
Clarke, E. Percy.
1935 English barley, 1935. J. Inst. Brewing **32**: 438–440.

Coleman, D. A.
1935 Report of the committee on standardization of methods for brewing and malting control. Cereal Chem. **12**: 575–595.
1936 Experimental malting at the United States Department of Agriculture. Intern. Brewing Abst., August 1936.
——, and Snider, S. R.
1935 The determination of moisture in barley malt. Cereal Chem. **12**: 621–645.
Deplanque, R.
1936 Sisto-und Eleutoamylase. Wochschr. Brau. **53**: 137–141.
——, and Lampe, B.
1935 Ueber Diastase und die Bestimmung der diastatischen Kraft, insbesondere des Grünmalzes. Wochschr. Brau., **52**: 156–159; 205–208; 222–224; 254–255.
Desnoullet, O.
1935 Flaked malt. Petit J. brasseur, **43**: 329. Abst. J. Inst. Brewing, **32**: 220.
Dickson, J. G., Shands, H. L., Dickson, A. D., and Burkhart, B. A.
1935 Barley and malt studies. I. Developing new varieties of barley for malting and their properties. Cereal Chem. **12**: 596–609.
Enders, C.
1936 Fortschritte in der Farbenbestimmung von Würze und Bier. Wochschr. Brau. **53**: 89–93. Objektive Farbbestimmung durch Absorptionsmessung. *Ibid.* **53**: 121–124; 131–132. Ueber Trübungen in Würze und Bier. *Ibid.* **53**: 201–203; 211–216. English Translation—Intern. Brewing Abst., May, June, July 1936.
Fink, H.
1935 Beiträge zur Auflösung des Malzes. Wochschr. Brau. **52**: 265–267.
——, Haehn, H., and Zenger, E.
1936 Ueber die Bildung von Atmungsenzymen im Verlauf der Gerstenkeimung. Wochschr. Brau. **53**: 65–69; 73–77; 83–87; 93–95; 101–103.
Geddes, W. F., and Eva, W. J.
1935 Second annual survey of the protein content of Western Canadian barley. Crop 1935. Dominion Grain Research Laboratory, Winnipeg. (Mimeographed Report.)
Hanes, C. S.
1935 The action of the two amylases of barley. Can. J. Research **13 C**: 185–208.
Hartong, B. D.
1936 Der Lösungsgrad des Malzes. Wochschr. Brau. **53**: 81–83.
Heinisch, O.
1936 Die Gerstenqualitäten der Gebiete des mittleren Donaulaufes im Bilde der heurigen Gerstenschauen. Wochschr. Brau. **53**: 3–5.
Henwood, A., and Garey, R. M.
1936 J. Franklin Inst.
Hess, E. M., and Maerzinger, J.
1936 Nacktgerste als Braumaterial. Bauer-u. Hopfen-Ztg. Gambrinus **63**: 3–5.
Holden, E. D.
1936 Education for barley improvement in Wisconsin. Am. Brewer **69**: No. 3, 15–19.
Ivanov, N. M.
1935 The biochemical characteristics of the barleys of the Soviet Union. Bull. Applied Botany, Genetics, Plant Breeding (USSR) Series III, No. 7, 175. (Chem. Abst. **30**: 229.)
Johnston, W. H., and Aamodt, A. S.
1935 The breeding of disease-resistant smooth-awned varieties of barley. Can. J. Research **13 C**: 315–338.
Kolbach, P.
1935 Der heurige Stand der Eiweissfrage. Wochschr. Brau. **52**: 209–214.
Kopecky, O.
1935 Ber. Inst. Gärung, Brünn **37**: 1.
Lecorvaisier, H.
1935 De l'hydrolyse de l'amidon d'orge suivant la nature de l'orge. 4th Intern. Tech. Chem. Congress Agr. Ind., Bruxelles (July 1935). Abst. Brewing Trade Rev. **39**: 427.

Leopold, H., and Horak, W.
1935 Studium neuartiger Beschädigungen an einer Braugerste. Wochschr. Brau. **52**: 409–414; 422–424.
Lüers, H.
1935 Die Entwicklung der Enzyme beim Mälzen. Wochschr. Brau. **52**: 249–254. English Translation—Cereal Chem. **13**: 153–171, 1936.
——, and Geiger, O.
1935 Der Hordeingehalt von Malzen. Wochschr. Brau. **52**: 193–195.
——, and von Miller, P.
1935 Eine neue Gerstenextraktbestimmungmethode. Wochschr. Brau. **52**: 153–154.
Myrbäck, K.
1935 Recherches sur l'analyse et la decomposition de l'amidon dans l'orge et le malt. 4th Intern. Tech. Chem. Congress Agr. Ind., Bruxelles (July 1935).
Newton, M., and Johnson, T.
1936 Stripe rust, Puccinia Glumarum, in Canada. Can. J. Research **14 C**: 89–108.
Nilsson-Ehle, H.
1935 Création de nouvelles variétés d'orge en Scandinavie. 4th Intern. Tech. Chem. Congress Agr. Ind., Bruxelles (July 1935).
Nowak, G., and Enders, C.
1936 Grundsätzliche Betrachtungen über die Wasserbestimmung in Gerste, Malz und Hopfen. Tztg. Brauerei **34**: 323–325.
Petit, P.
1935 Color in worts and beers. Brasserie et Malterie **25**: 161–166. Cf. Wochschr. Brau. **52**: 397–398.
1935*a* Analysis and evaluation of malt. *Ibid.* **25**: 113–117. Abst. J. Inst. Brewing **32**: 382.
Piratzki, W.
1936 Ueber die Viskosität von Malzwürzen. Wochschr. Brau. **53**: 105–108.
Raux, J.
1935 Consequences of reduction in the proportion of raw grain. Brasserie et Malterie **25**: 149–157. Abst. J. Inst. Brewing **32**: 413.
Rose, R. C., and Anderson, J. A.
1936 Fractionation study of barley and malt proteins. Can. J. Research **14 C**: 109–116.
Schild, E.
1935 Die Zusammensetzung der formoltitrierbaren Eiweissabbauprodukte in Gerste und Malz. Wochschr. Brau. **52**: 321–325.
Schultz, K. G., and Kunisch, G.
1935 Vereinfachung und Beschleunigung der Wasser und Eiweissbestimmung bei Braugersten. Wochschr. Brau. **52**: 289–294.
Shellenberger, J. A., and Bailey, C. H.
1936 Experimental malting. Brewers' Tech. Rev. **11**: 3–5.
Siegfried, H.
1936 Bestimmung des Gerstenextraktes nach verschiedenen Arbeitsmethoden. Schweiz. Brau. Rundschau **46**: 161–162.
Tapke, V. G.
1935 A study of the causes of variability in response of barley loose smut to control through seed treatment with surface disinfectants. J. Agr. Research **51**: 491–508.
Thorpe, S. K.
1935 Foreign barley during the past twelve months. J. Inst. Brewing **32**: 440–444.
1936 Foreign and Colonial barleys, 1935. *Ibid.* **33**: 235–240.
Thunaeus, H., and Schroederheim, J.
1935 Ueber die Sorteneigenschaften der Barugerste. Erfahrungen aus den schwedischen Braugerstenversuchen 1926–1934. Wochschr. Brau. **52**: 357–362; 369–373.
Thunberg-Ahlgreen
1925 Skand. Arch. Physiol.: Supplement to Vol. 47, 1. Also Vol. 35, 163.
1936 Cf. Wochschr. Brau. 53, 67
Waldschmidt-Leitz, E., and Mayer, K.
1935 Ueber Amylophosphatase aus Gerste. (5. Mitteilung über enzymatische Amylolyse.) Z. physiol. Chem. **236**: 168.

FACTORS WHICH INFLUENCE RESULTS IN THE WHEAT-MEAL-TIME-FERMENTATION TEST [1]

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The desire and use, based on need, for simple tests to measure the quality of wheat or flour antedates the establishment of modern cereal laboratories. The newer and comparatively elaborate facilities may cause cereal chemists to overlook the virtues in some of the simpler methods. It is reported that William Saunders, the originator of Marquis wheat, used only his eyes and teeth for quality testing. However, he could use these simple methods because his knowledge and experience enabled him to make that interpretation which led to the right selection. The old and simple gluten washing test was, in its day, one of the most valuable tests in the hands of an experienced and artistic operator.

One of the advantages of the simple tests, such as gluten washing, is that only small quantities of material are required. Any simple but reliable test which can be made on about an ounce of wheat is of particular advantage to the wheat breeder as it enables him to discard inferior strains or varieties much earlier in the wheat improvement program. To obtain enough wheat for a milling and baking test requires 7 to 10 years in the ordinary routine of wheat hybridization.

The "Time" Test

The wheat-meal-time-fermentation test meets the demands for smallness of material and apparent simplicity of operation so that a large number of samples can be tested. The reliability and especially the meaning of the results are far from settled. In this paper will be reported some investigations on factors which influence the results of the "time" [4] in the test.

It appears that the test was first used by H. A. Saunders (see Wynot, 1926; Saunders and Humphries, 1928) in the Coxes Lock Mill, Weybridge, England, who developed the method on the basis of his ob-

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[4] The word "time" will be used to designate the number of minutes which elapse from the moment the dough ball is placed on the water until disintegration is observed to start on the under side. This "time" expressed in minutes is taken as the measure for quality. The words "time test" will also be used instead of the longer expression.

servations in testing wheat and flour for quality. Saunders made the dough ball with 10 g. of flour, 6 cc. of water, and ½ g. of yeast, all at 80° F. when mixed. The dough ball was floated on water at 80° F. in a small vessel. The advantage of floating the ball on water was to protect it from shocks and one requirement in the original test was that the ball should be free floating and not supported by the walls of the vessel. Saunders found that the "time" was longest for flours made from Manitoba wheats and shortest for flour from English wheats.

Pelshenke (1930 and 1933) used 5 g. of wheat meal, ¼ g. of yeast and enough distilled water to make a ball of medium stiffness which was floated on water at 88° to 91° F. He obtained a variation in "time" on different wheats from 24.5 to 138.7 minutes, while the spread in loaf volumes was only from 348 to 443 cc., the Brabender farinograph gluten quality number varied from 70.1 to 98.3, and the Berliner swelling number varied from 1 to 25. Thus the "time" varied more among the different wheats than the results of any other test except the last.

The data of Cutler and Worzella (1931, 1933) did not show a correlation of "time" and loaf volume, but significant correlations did appear between "time" and absorption and vitreous kernels respectively. The longest "time" was obtained from the high protein spring wheats, followed next by the high protein hard red winter wheats. The low protein hard winter wheats, the soft red winter wheats, and the white followed in "time" in the order named.

Wilson, Markley, and Bailey (1933) found that the "time" test was not significantly correlated with protein percentage and loaf type. It was probably correlated significantly with loaf volumes and strength score. These authors point out that variation in technique will affect the final results. Bayfield (1935) has presented some factors producing variation in the whole meal "time" data.

Swanson and Parker (1935) found that tempering hard wheat increased the "time" probably because of the finer granulation produced in grinding the sample.

Experimental Effect of Granulation

That fineness of grinding may make a considerable difference in "time" has been found by users of this test and hence this procedure must be as uniform as possible for the different samples. As a rule, the coarser the grinding the shorter the "time," and the finer the meal the longer the "time." In the coarser meal more of the endosperm is in chunks and does not contribute as much to the dough mass as when the meal is more fine.

To demonstrate the effect of the variation in granulation produced

by grinding, wheat samples from four varieties, Tenmarq, Turkey, Quivira, and Early Blackhull, were ground in the well known Wiley mill. This mill is particularly adapted to prepare meals of varying granulation since the grinding is continued until all the material passes a given screen. The three screens with circular openings—1.5 mm., 1.0 mm., and 0.5 mm.—were used in turn for grinding wheat samples of the four varieties mentioned. To avoid any effect that might result from the aging of the meal, the tests were made the day after grinding. The results obtained on the meals of the three granulations are given in Table I.

TABLE I

EFFECTS OF FINENESS OF GRANULATION ON THE "TIME" FOR DOUGH BALLS TO BREAK

Variety	Granulation		
	0.5 mm.	1.0 mm.	1.5 mm.
	Minutes for dough balls to break		
Tenmarq	191	171	129
Turkey	116	100	72
Quivira	127	100	70
Early Blackhull	74	69	64

The fineness of grinding made the least difference on Early Blackhull as compared with the other three indicating that with varieties which normally have a short "time," the method of grinding is not as important as with varieties which have a long "time." The longer "time" was obtained for the fine and the shorter "time" for the coarser granulation in each variety. However, regardless of granulation the "time" was longest for Tenmarq and shortest for Early Blackhull, with Turkey and Quivira intermediate, indicating that in varieties which vary considerably in "time" the longer and shorter "time" will be obtained whether the meal is ground coarse or fine, but in varieties which differ little in "time," such as Turkey and Quivira, the method of grinding may entirely obscure differences due to variety. Inasmuch as the use of the Wiley mill was too slow for routine testing, after a large number of trials a burr mill was adopted in its place. Grinding on this type of mill to pass a 40 wire proved to give more consistent results than any other method of grinding. Since the method of grinding, as far as it affects granulation, may have a greater effect on "time" than differences due to variety, it therefore becomes exceedingly important that the method of grinding be uniform. This is particularly true for varieties which have a long "time."

Amount of Mixing the Dough

In experimenting with various wheat varieties it was found that the amount and manner of working the dough would make a difference in "time." This part of the technique was solved by using a small mechanical dough mixer, designed by E. B. Working. This machine will handle a dough made from 15 to 25 g. of flour or meal. The usual amount used is 15 g. since this amount of dough when divided into three equal parts makes "balls" of convenient size to float on the water held in ordinary drinking glasses. These glasses, of course, cost much less than beakers.

It is a well known fact among bakers that various flours differ in amount of mixing required to develop the dough. This seems to be largely inherent in the wheat variety from which the flour was made. In experimenting with this machine it was found that the amount of mixing necessary to make a dough of smooth consistency varied in wheat varieties of different characteristics. This observation agreed with the more exact data found in the curves produced by the Swanson-Working recording dough mixer. No fixed rule can be established by which the length of mixing can be guided. The only guide is careful observation of the dough in the mixer. It has been found that the amount of mixing varies from 50 to 180 seconds in different varieties. How long to mix must be learned by experience.

Amount of Absorption

The amount of water used in making the meal was also found to affect the "time." Since it is desired to adapt the test, especially in wheat improvement work, to small samples, a preliminary absorption determination is not practicable. It has been found best to start with a little less than the probable amount of water needed. Then as the dough develops in the bowl the operator judges from the appearance the approximate amount of additional water that should be added. This is best done by a physician's syringe.

Influence of Temperature

Temperature is one of the most important factors in "time" since we are dealing with the activity of the biological agent yeast. The temperature now used is as near 30° C. as possible. The glasses used in making the test have a capacity of 270 cc. and an inside diameter at the top of approximately 65 mm. These are nearly filled with distilled water at 30° C. about 2 to 3 hours before making the test and placed in the temperature controlled cabinet provided with both heating and cooling devices. It is not advisable to have the glasses in the cabinet for a long time, such as overnight, since the concentration of carbon dioxide

in the water becomes appreciably higher and this itself lengthens the "time" as will be shown more in detail later. The temperature of the water in the glass is taken at the same moment as the "time" is recorded in order to guard against accidental fluctuations in temperature. It is also necessary to have the room at a fairly even temperature which is not difficult except in hot weather when a temperature controlled room would be necessary.

To maintain the dough at near the desired temperature, the bowl is kept between mixings in water somewhat above the temperature of the room. During mixing the dough tends to approach the temperature of the room which is about 25° C. although the yeast suspension when added is at 30° C. Starting with a warm bowl minimizes this drop so that the handling in the operator's hands soon warms the dough to 30° C. A small variation in dough temperature is not serious since the potential calorie value of the 190 cc. water in the glass is large in comparison with the dough ball made with 5 g. of meal or flour.

Influence of Storing After Grinding

In several trials it had appeared that the "time" obtained was not the same if the tests were made several days after grinding as if they were made the same or the next day. This was found to be true of varieties which had a short "time" as well as those which had a long "time." To test this more extensively, tests were made on meal from Tenmarq wheat ground the same day, and after storing for various periods. The results obtained over a period of 8 to 9 weeks are given in Table II.

TABLE II

"TIME" OBTAINED WHEN SAMPLES WERE TESTED SOON AFTER GRINDING, AS COMPARED WITH TESTING AFTER STORING FOR VARIOUS PERIODS

Ground a short time before testing		Ground November 7	
Date tested	*Minutes*	*Date tested*	*Minutes*
Nov. 8	143	Nov. 7	153
Nov. 9	141	Nov. 9	149
Nov. 11	148	Nov. 13	173
Nov. 13	147	Nov. 14	179
Nov. 18	136	Nov. 16	179
		Nov. 21	176
		Nov. 23	198
Dec. 13	143	Dec. 3	206
Dec. 26	140	Dec. 6	210
Dec. 31	140	Dec. 16	234
		Dec. 27	210
Jan. 6	149	Jan. 6	242
Jan. 7	139		
Jan. 9	138		
Jan. 14	148		
Jan. 16	135		

The data on the samples of Tenmarq wheat tested soon after grinding show the variation which may be obtained on the same lot of wheat. The longest time was 149 minutes and the shortest 135, or a range of 14 minutes which is not large when the "time" is as long as it is for Tenmarq. The effect of storing after grinding was marked as there was a range from 149 to 242 minutes. The cause of this increase in "time" when meal is stored has not been learned, but because there is a change in the meal which increases the "time," the practice is to grind the meal only a day or two before the test is made.

Different Types of Dough Disintegration

After fermentation has continued a few minutes the ball which at first sinks to the bottom, becomes buoyant because of swelling from the retained gas and rises to the surface and floats. When the "time" is short, 25 to 40 minutes, disintegration starts while the ball is in a spherical or slightly flattened form. When the "time" is longer, the ball assumes a more flattened appearance. When the "time" is long the ball becomes a flat disc and covers the surface of the water in the glass. The end-point is easier to observe when the "time" is short than when long. Long "time" dough balls may start to droop around the edges and a part of the edge break away. In others, thin bag-like films form on the under side and break. In still others, the edges droop and curl resulting in the whole mass sinking. Because of these differences in behavior, the operator needs a large amount of experience in judging the behavior of the dough ball "time."

Effect of Adding Substances from Wheat to Flour

Several trials had shown that the "time" (Swanson and Parker, 1935) obtained on flour was not the same as that obtained on the wheat meal. To learn what effects various substances from the wheat had on "time," bran alone, shorts alone, and a mixture of bran and shorts were added to separate samples of flour. Bran extracted with water and the extract of this bran were also used. The bran and the shorts were from the same wheat variety as the flour but the germ was a commercial sample. The bran and shorts were ground to the usual fineness of wheat meal and the proportions added were estimated to be the same as they would be in the natural wheat meal. The germ was ground to a similar fineness but was used in a much larger proportion than present in wheat meal. The bran was extracted by soaking 50 g. of bran in 200 cc. of water for 18 hours, filtered through linen cloth and then spread out and exposed until air dry, after which it was ground. The bran extract was placed in a cylinder and allowed to settle. The clear

extract on top was used in making the dough ball. The results obtained are given in Table III.

TABLE III

EFFECT ON "TIME" OF ADDING SUBSTANCES FROM WHEAT TO FLOUR

Substances added	Variety				Remarks
	Tenmarq	Turkey	Quivira	Early Blackhull	
	Minutes for dough balls to break [1]				
Wheat meal	145	54	77	62	Averages of 2 trials.
Flour	85	93	88	75	Averages of 3 trials.
Flour + bran	290*	226*	215	174	12.5 g. flour + 2.5 g. bran.
Flour + shorts	199	201	172	164	12.5 g. flour + 2.5 g. shorts.
Flour + bran + shorts	401*	335	278	175	10.8 g. flour + 2.4 g. bran + 1.8 g. shorts.
Flour + extracted bran	271*	267*	263*	243	12.5 g. flour + 2.5 g. extracted bran.
Flour + water extract of bran	124	126	95	125	15 g. flour + extract from 2.5 g. bran.
Flour + wheat germ	135	126	127	124	12.5 g. flour + 2.5 g. germ.

[1] The asterisk (*) indicates that the dough ball had not broken but the trial was stopped at the end of this time. Experience had shown that "time" beyond 200 minutes has little meaning because of the diminishing yeast food supply.

The results obtained on the flours alone are different from those obtained on the wheat meal, especially with Tenmarq. Turkey had the shortest "time" on the meal and the longest on the flour. Tenmarq had the longest on the meal and next to the shortest on the flour. Since flour and not wheat meal is used in baking these results raise the question as to what the "time" in this test means in wheat testing.

The addition of bran or shorts greatly increased the "time" over that obtained on the meal. The increase was still greater when both were added. Addition of extracted bran increased the "time" more than the unextracted. Making the dough ball with the water extract of the bran and the addition of wheat germ made the "time" on all the varieties more nearly the same. That is, the addition of such substances masks differences in "time" due to variety.

Apparently it is the bran substance which increases the "time" and extracting with water does not decrease its effectiveness. The shorts does not decrease the "time" as much as the bran and apparently because the amount of bran material is less. Water extract of bran is sometimes used in baking to stimulate fermentation. Hence the increase in "time" on three of the varieties when the dough ball was made with flour and bran extract as compared with the "time" when it was made

with flour and water, was not due to a slower fermentation. These various results suggest that some of the substance which causes differences in "time" among varieties is located in the bran. More work is needed to confirm this supposition.

Influence of Amount of Bran or Germ Material

In another trial the amount of bran and germ both finely ground and added to straight flour, was varied. The results are given in Table IV.

TABLE IV

EFFECT OF VARYING AMOUNTS OF BRAN AND GERM

	Minutes		Minutes
Straight flour	105	Straight flour + 0.5 g. germ	134
Straight flour + 0.5 g. bran	158	Straight flour + 1.25 g. germ	185
Straight flour + 1.25 g. bran	217	Straight flour + 2.50 g. germ	265
Straight flour + 2.50 g. bran	214*		

It is evident that the amount of bran and germ has a pronounced effect on the "time."

The "Time" on Some Mill Stream Flours

The "time" was determined on a few mill stream flours taken at two different times and so selected as to have various degrees of freedom from bran material. The results obtained are given in Table V.

TABLE V

"TIME" ON A FEW MILL STREAM FLOURS OF TENMARQ WHEAT

	Dough ball "time," minutes	
Flour stream	1st	2nd
1st break	81	108
4th break	136	252*
Sizings	77	99
1st middlings	53	99
4th middlings	75	109
1st tails	96	106
Low grade	93	118
Patent	74	
Clear	93	

It is apparent that the "time" is longer with those flours which are known to have the higher ash or more bran particles. The results in Tables III, IV, and V seem to indicate that the substances in the bran have more to do with determining the "time" than those in the endo-

sperm. If that is the case, it would throw grave doubt on the value of the "time" test since it is the endosperm in the form of flour which is used in baking.

Effect of Inert Substances

The important question is: why do these substances increase the "time"? It has already been stated that retardation of yeast growth is not probable because bran material has a stimulating effect. The mechanical effect of the presence of inert substances was studied by mixing powdered pumice, alundum powder, and paper pulp with the flour. The results obtained are given in Table VI. The "time" ob-

TABLE VI

EFFECT ON "TIME" OF ADDING INERT MATERIAL TO FLOUR

Mixture	Variety			
	Ten-marq	Tur-key	Qui-vira	Early Blackhull
	Dough ball "time," minutes			
Flour alone	85	93	88	75
12.5 g. flour + 2.5 g. alundum	81	77	83	80
12.75 g. flour + 2.25 g. paper pulp	91	86	98	114
14.25 g. flour + 0.75 g. paper pulp	83	97	87	79
12.5 g. flour + 2.5 g. pumice	127	112	114	125

tained with alundum was practically the same as with flour alone, neither did the use of paper pulp produce any marked change in time except with Early Blackhull. Alundum and paper pulp differ greatly in physical characteristics, alundum being composed of solid, irregular particles with much less surface that the fibrous material in the paper pulp. Hence the physical form of some of the inert material does not seem to be the important factor. Pumice markedly increased the "time" over the flour alone. Pumice is inert the same as alundum, but its physical form is different in that the particles are porous.

Effect of Certain Compounds

The next trial was to ascertain the effect of adding lecithin to flour and also oleic acid, which may be present in the wheat fat. The *N*-caproic and the pelargonic acids were added to compare the effects of these saturated acids with the unsaturated oleic acid. The oxidizing salts $KBrO_3$ and $KClO_3$ were also tried. The results obtained are given in Table VII.

TABLE VII

EFFECT OF ADDING LECITHIN, ORGANIC ACIDS[1] AND OXIDIZING AGENTS[2] TO FLOUR

Mixture	Variety			
	Tenmarq	Turkey	Quivira	Early Blackhull
	Dough ball "time," minutes			
Flour alone on 3 trials	85	93	88	75
Flour + lecithin	98	102	87	85
Flour + oleic acid	93	96	90	73
Flour + lecithin + oleic acid	97	98	84	82
Flour + *N*-caproic acid	100	122	114	60
Flour + pelargonic acid	200*	200*	200*	171
Flour + $KBrO_3$	105	123	94	76
Flour + $KClO_3$	93	98	86	73

[1] The lecithin and organic acids were added in the proportion of 1 mg. for each gram of flour.
[2] The oxidizing agents were used in the amount of 1 mg. for each 10 cc. of water used in making the dough ball.

The effects of lecithin and oleic acid either alone or in combination were comparatively slight. Hence it is not probable that it is the presence of substances similar to these which make the effect of bran or shorts so marked. It has already been shown that the "time" increases when wheat meal is allowed to stand some time before the trial is made. Oleic acid might be produced under these conditions and the amount would probably not be greater than that added in these trials. These results indicate that it is not an unsaturated acid such as oleic which is responsible for the increase in "time" when wheat meal ages. The *N*-caproic acid increased the "time" as compared with flours alone from three of the varieties and shortened it on Early Blackhull. The increase in "time" was most marked with use of pelargonic acid but early Blackhull had the shortest "time." The increase in "time" when wheat meal is stored may be due to the production of some substances which have an effect similar to these two saturated acids. It is noteworthy that the shortest time was obtained with both acids on Early Blackhull.

Effect of Extracting Flour with Petroleum Ether and Absolute Alcohol

The next experiments were made on flour from Tenmarq and Early Blackhull extracted with petroleum ether and absolute alcohol. The extractions were made by thoroughly mixing with and then soaking the flours in these liquids, decanting, then adding more of the liquids and then thoroughly mixing by shaking the flasks. This addition of the

solvent, soaking, and decanting was continued until the supernatant liquid was almost free from yellow color. With the last decanting the flour was transferred to a large funnel so as to drain off most of the liquid. After draining, the flour was spread in shallow dishes and air dried. The flours thus extracted were then used in various "time" tests with results given in Table VIII.

TABLE VIII

EFFECT IN "TIME" OF ADDING LECITHIN AND ORGANIC ACIDS TO EXTRACTED FLOURS

Substances added	Tenmarq		Early Blackhull	
	Extracted with		Extracted with	
	petroleum ether	absolute alcohol	petroleum ether	absolute alcohol
	Dough ball "time," minutes			
Unextracted flour	85		75	
Extracted flour alone	77	146	57	98
Flour + 0.2% lecithin, egg	87	164	67	101
Flour + 0.2% lecithin, flour	87	144	58	98
Flour + 0.2% oleic acid	89	163	61	96
Flour + 0.2% *N*-caproic acid	69	192	42	77
Flour + 0.2% pelargonic acid	227*	227*	180	213*
Flour + 0.2% lecithin, egg Flour + 0.2% oleic acid	91	153	62	96

Extracting with petroleum ether shortened the "time" and extracting with absolute alcohol lengthened the "time" over that obtained on the unextracted flours. The addition of lecithin whether in pure form from egg or in impure form from flour increased the "time" a small amount in most cases. The same may be said of the effect of oleic acid either alone or in combination with lecithin. The figures in Table VII show that the addition of oleic acid and lecithin have a tendency to increase the "time." This indicates that the shortening of the "time" on the petroleum ether extracted flours is due to the removal of substances similar to these. *N*-caproic acid increased the "time" for the alcohol extracted Tenmarq flour but decreased it in all other cases. Pelargonic acid increased the "time" in all cases.

Whatever may be the meaning of the effects of the additions of these substances to the extracted flour the differences in these two varieties still persist. With all these treatments or additions of substances, the "time" on Early Blackhull is shorter than on Tenmarq.

Extracting Wheat Meal

Since wheat meal is, as a rule, used in these " time "tests, extractions were also made on the meal from Tenmarq and Early Blackhull, using the same procedure as with the flour but including also ethyl ether. The determinations of " time " obtained are given in Table IX.

TABLE IX

EFFECT OF EXTRACTING WHEAT MEAL WITH ETHYL ETHER, PETROLEUM ETHER, AND ABSOLUTE ALCOHOL

	Variety	
	Tenmarq	Early Blackhull
	Dough ball "time," minutes	
Check, meal	145	62
Ethyl ether	205	70
Petroleum ether	201	80
Absolute alcohol + ethyl ether	330+	289
Absolute alcohol + petroleum ether	330+	330+

Extracting the meal with ethyl ether or petroleum ether increased the " time " while for the flour there was a decrease (Table VII). The " time " was still further increased when the additional extraction was made with alcohol. As with the flours, the " time " is shorter for Early Blackhull than for Tenmarq after these extractions.

Effect of Adding Water to Wheat

Water was added to wheat in two Erlenmeyer flasks to make the moisture content a little over 40% and to wheat in another flask to make it 16%. The wheat and water were thoroughly mixed so that no free water collected on the bottom. The 16% moisture wheat and the wheat from one flask having 40% moisture were spread after 24 hours and the other 40% moisture wheat was spread after 72 hours so as to become aid dried. These wheats were then ground and the " time " determined with the results given in Table X.

TABLE X

EFFECT OF TREATMENT OF WHEAT WITH WATER

	Variety			
	Tenmarq	Turkey	Quivira	Early Blackhull
	Dough ball "time," minutes			
Check	144	53	76	61
24 hours, 16% water	152	75	101	67
24 hours, 40% water	140	46	49	63
72 hours, 40% water	67	34	36	37

The adding of water to make the moisture content 16% had a little effect on Tenmarq and Early Blackhull, but increased the "time" of Turkey and Quivira. This indicates that for some wheats which are hard and flinty, the "time" may be increased if water is added to make them softer so as to grind finer. The treatment with water at 40% for 24 hours shortened the time for Turkey and Quivira but not for Tenmarq and Early Blackhull. The shorter "time" obtained on all the wheats from the 72-hour treatment shows that the process of germination shortens the time apparently in proportion to the length or duration of this process. The varietal effect is shown in Tenmarq which even after the 72 hours' treatment still had a longer "time" than the other three wheats.

Effect of CO_2 Concentration in the Water Used to Float "Ball"

It had been observed that the "break" in the dough ball always took place from the under side of the dough ball. The escape of carbon dioxide was also observed to take place on the under side. Since carbon dioxide is soluble in water, the escape would be facilitated by its absence in the water and hindered by its presence. To learn the effect on "time" of preventing in various degrees the escape of carbon dioxide from the dough ball, various concentrations of carbonated water were used in the glasses in which the dough balls were floated. These concentrations were obtained by mixing fully saturated carbonated water with various amounts of CO_2 free water. The proportions used were: all carbonated, 2 to 1, 1 to 2, and no carbonated water. For comparison, one set of tumblers had ordinary distilled water which contained some CO_2. The results obtained are given in Table XI.

TABLE XI

EFFECT ON "TIME" OF FLOATING DOUGH BALLS ON VARIOUS CONCENTRATIONS OF CARBONATED WATER

Variety	All carbonated	2 to 1 carbonated	1 to 2 carbonated	CO_2 free	Ordinary distilled
	Dough ball "time," minutes				
Tenmarq	288	183	145	135	142
Early Blackhull	77	66	61	51	57

The presence of CO_2 in the carbonated water hindered the escape of CO_2 from the dough and increased the "time" in proportion to the saturation. The effect was greater on Tenmarq than on Early Blackhull. As with the other experiments, the "time" of Early Blackhull remains shorter than that of Tenmarq.

Summary

It has been shown that the results of the wheat-meal-time-fermentation test are influenced by a number of factors other than the quality inherent in the wheat or flour tested.

The finer the wheat meal is ground the longer the "time" and the coarser it is ground the shorter the time.

The amount of mixing will influence the "time" and should be varied with the characteristics inherent in the wheat variety. This is best done by a small mechanical mixer. With the use of this machine it is also possible to add more water to obtain the optimum absorption.

The temperature of the ingredients must be carefully controlled and the fermentation must be done in a cabinet controlled within 0.1° or 0.2° C.

The length of storage between grinding and testing influences the "time." It is best to make the test either the same day as the meal is ground or the day after.

There are several types of dough ball disintegration and careful observation and experience are needed in order to get informative results.

The addition of ground bran, shorts, or germ to the flour changes the results to such an extent as to mask differences in "time" due to variety. Since it is the finely pulverized endosperm which is used in baking, and since these substances seem to have such a great effect on the "time," a grave question is raised as to the meaning of the "time" test.

Flours from mill streams which normally have fewer bran particles have a shorter "time" than flours which have more bran particles.

Some inert substances such as powdered pumice increased the "time" while other inert substances such as paper pulp and alundum had very little effect on "time."

The saturated acids *N*-caproic and pelargonic markedly increased the "time" while lecithin and the unsaturated oleic acid had little effect on "time." The oxidizing salts $KBrO_3$ and $KClO_3$ also had no consistent effect on "time."

Extracting with petroleum ether shortened the "time" on flour but not on meal and extracting with absolute alcohol lengthened the "time" on both.

Adding water sufficient to start germination decreased the "time," but adding water only to mellow the wheat so as to grind finer increased the "time."

The concentration of carbon dioxide in the water on which the dough ball floats had a marked effect on "time." The "time" of Tenmarq when floated on water saturated with carbon dioxide was

about double the "time" obtained when ordinary distilled water was used.

In varieties like Early Blackhull and Tenmarq which differ much in "time," Early Blackhull always had the shorter time and Tenmarq the longer "time" in these various manipulations. With varieties which do not differ much in "time" it is evident from these observations that the differences in "time" may easily be masked by methods of performing the test, by conditions in the laboratory, or by the addition of certain substances.

Literature Cited

Bayfield, E. G.
1935 Soft winter wheat studies. IV. Some factors producing variation in the whole meal time data. Cereal Chem., **12**: 559–568.
Cutler, G. H., and Worzella, W. W.
1931 A modification of the Saunders test for measuring quality in wheats for different purposes. J. Am. Soc. Agron., **23**: 1000–1009.
1933 The wheat-meal-fermentation-time test of quality in wheat adapted for small plant breeding samples. Cereal Chem., **10**: 250–262.
Pelshenke, Paul
1930 Beiträge zur Bestimmung der Backfähgkeit von Weizen und Weizenmehlen. Arch. Pflanzenbau, **5**: 1.
1933 A short method for determination of gluten quality of wheat. Cereal Chem., **10**: 90–96.
Saunders, H. A., and Humphries, S.
1928 The Saunders test. J. Natl. Inst. Agr. Bot., **2**: 34.
Swanson, C. O., and Parker, J. H.
1935 The wheat-meal-time-fermentation test. Production annual, Northwestern Miller, Oct. 16, 1935.
Wilson, H. K., Markley, M. C., and Bailey, C. H.
1933 The wheat-meal-time-fermentation test. Cereal Chem., **10**: 619–620.
Wynot, William
1926 The Saunders process. Milling, Vol. 66, p. 786–88, June 26.

THE COLLOIDAL BEHAVIOR OF FLOUR DOUGHS. I. THE THIXOTROPIC NATURE OF STARCH-WATER SYSTEMS [1]

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(Received for publication January 4, 1937)

The rôle of starch in flour doughs has long been considered to be merely that of a filler and a substrate for amylase activity. This view probably grew out of the early work upon the viscosity of dilute flour-water suspensions in which the protein appeared to be all-important and the starch to be without effect. When systems such as bread doughs in which the flour concentration exceeds the water content by as much as 100% are considered it is possible that conditions may be quite different from flour suspensions where there is four to ten times as much water as flour. Little is recorded about the properties of starch in systems as concentrated as a bread dough.

In order to determine if the starch does play an important rôle in flour doughs, a starch-water system was studied by means of the Brabender farinograph. The farinograph is essentially a plastometer consisting in a dough mixer driven by a constant-speed motor and provided with a recording dynamometer. The dynamometer record is a graph in which torque values, expressed as grams at 20 cm. radius, are plotted against time. These torque values, commonly called Brabender units, may be considered to be directly proportional to the viscosity or inversely proportional to the mobility of the material in the mixer-bowl. Provision is made for controlling the temperature of the mixer-bowl. The starch used in this study was a commercial untreated wheat starch of confectioners' grade secured from the Huron Milling Company. After some preliminary work a mixture of 300 g. of starch and 213 cc. of distilled water was found to be satisfactory for use in this study. In Figure 1 is shown the graphical record drawn by the instrument when mixing this amount of starch and water. The viscosity rose very rapidly during the first minute while the water was being added, reaching momentarily a very high value, but very quickly dropped to about 500 units, which is normal for bread doughs. After reaching the 500-unit

[1] Published with the approval of the Director as Paper No. 1477, Journal Series, Minnesota Agricultural Experiment Station.

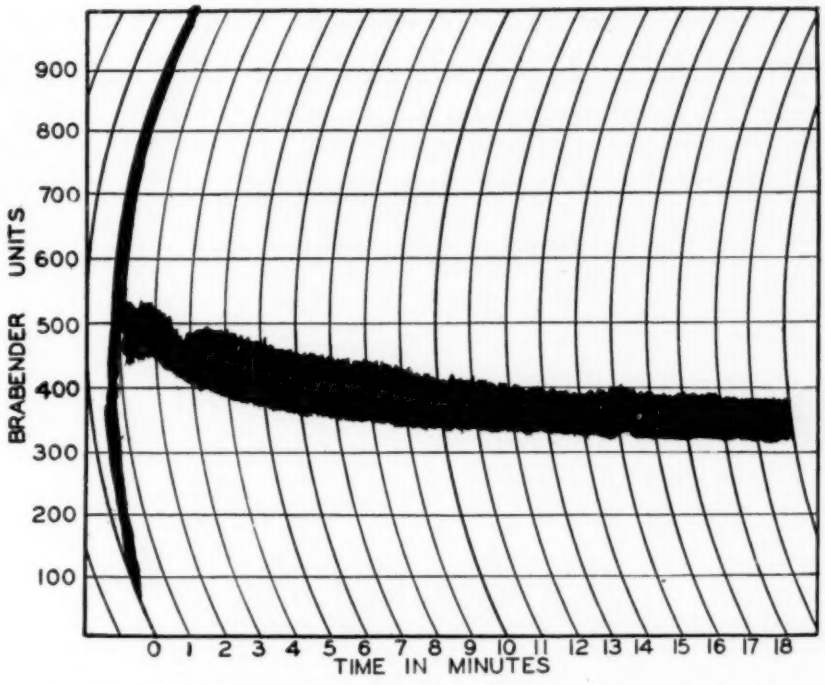

Figure 1. Relation between viscosity and time in a wheat starch-water system undergoing constant agitation in the farinograph.

level the fall in viscosity, or gain in mobility as some prefer, was decelerating, though the decrease continued throughout the 20-minute run.

The shape of the curve suggested that the system might be thixotropic. A thixotropic system is one which is a gel when quiescent, but which becomes a sol upon the application of a shearing force, but again becomes a gel when allowed to return to the quiescent stage. An excellent discussion of thixotropy has been given by Kistler [2] who explains it by means of the cyboma theory. Cybomas are fugitive liquid crystals in the water-phase of a sol which tend to concentrate near the surfaces of lyophillic colloidal particles; thus imparting a rigidity to the system beyond that imparted by the electrical forces acting between the particles. A thixotropic gel has a measurable yield point, and is elastic as long as this yield point is not exceeded, but when a shearing force causes this yield point to be exceeded the cybomas are quickly destroyed and the system becomes a sol; after the force is removed and the sol allowed to become quiescent the particles reassume their stable positions, and the cybomas reform and align themselves on the surfaces of the particles, thus reforming the gel. This process can be repeated many times.

[2] Kistler, S. S. On the nature of coagulation viscosity, and thixotropy in colloidal systems. Colloid Symposium Monograph, pp. 98–118 (1932).

In order to determine if a starch-water system is thixotropic, another test similar to that shown in Figure 1 was commenced, but the mixer was halted after 3 minutes, and the paste allowed to rest for 20 minutes at 30° C. At the expiration of this rest period the mixer was again started with the result that the second portion of the curve was almost identical in shape with the first; as is shown in Figure 2. This process

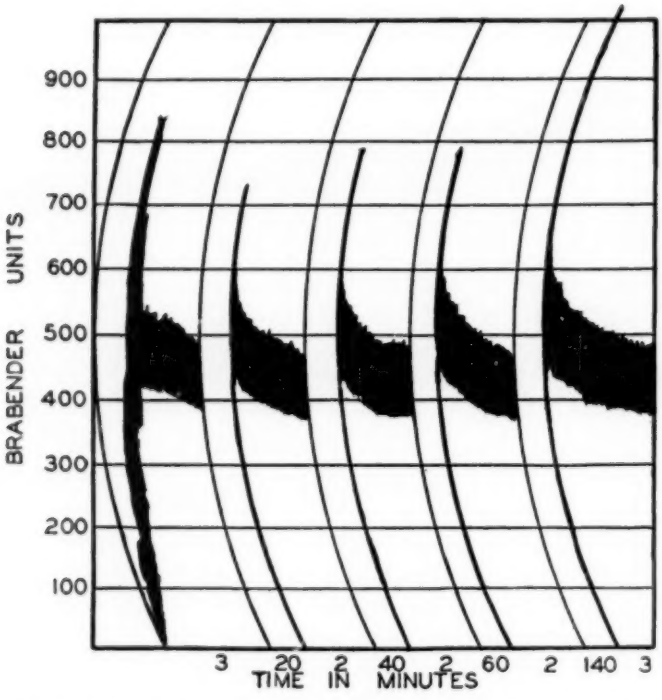

Figure 2. Relation between viscosity and time in a wheat starch-water system undergoing alternate periods of agitation and quiescence in the farinograph.

was repeated for successive rest periods of 40, 60, and 140 minutes with similar results. These findings indicate very clearly that the starch-water system studied is definitely thixotropic.

The high viscosity of the starch sol should be noted; during the second minute of mixing it lies between 400 and 500 Brabender units which is above the average level for flour-water doughs of the same proportions. This indicates that starch is one of the most important factors in determining the viscosity or the mobility of a dough, since it constitutes from 60 to 75% of the dry matter. The starch can no longer be ignored in the interpretation of physical observations made upon bread doughs, but always must be considered as an important major constituent.

GRAIN QUALITY OF COUCH GRASS AND WHEAT-COUCH GRASS HYBRIDS

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(Received for publication June 30, 1936)

In the fall of 1935 the Technological Laboratory of the Central Station for Plant Breeding and Genetics, located in Saratov, U.S.S.R., carried out an investigation relative to the grain quality of different species of couch grass and wheat-couch grass hybrids. The material for that purpose was obtained from the Division of Wheat-Couch Grass Hybrids, of the Saratov Station.

As already known, the principal factor indicating grain quality is gluten. Good bread of large volume and good texture can be obtained only when a sufficient quantity of this valuable protein is present in the flour. Up to the present it has been thought that wheat is the only plant capable of producing gluten. Even rye, a close relative of wheat, does not possess this ability in spite of the fact that it contains the same proteins as wheat—gliadin and glutenin.

The results of the present investigation, therefore, are of extreme interest as it has been shown that the couch grass is characterised by the presence of gluten in very large quantities. In addition to this fact, M. N. Roushenbach of the Saratov Station, has found that the couch grass grain is distinguished by a very large quantity of protein exceeding that of wheat by 5% to 9.5%. Individual couch grass species vary greatly with regard to their protein content as well as to the quality of the gluten. It is possible therefore to assume probable differences in the baking qualities of couch grass. At this time the baking qualities of one couch grass species, namely, *Agropyron intermedium*, has been investigated. Bread made from the couch grass flour was not as good as that made from wheat flour, but was much better than that of rye flour. In distinction to rye flour, couch grass flour develops a larger volume, better texture, and a lighter colour of crumb. Thus, it is reasonable to suppose that crosses of couch grass with wheat are more desirable with respect to ultimate grain quality than the crosses of wheat with rye. Moreover, it is believed that couch grass can be used to increase the protein quantity of wheat. This is of particular importance in the breeding of species for growth under irrigation conditions.

At the present time the Central Station of Plant Breeding and Genetics at Saratov has obtained a series of wheat-couch grass hybrids of wheat and of intermediate type hybrids, which, being not lower in their baking qualities than wheat, contain more albumen and gluten than the last.

Data are given below on the gluten quantity of some of the wheat-couch grass hybrids as well as their parental forms:

Name	Gluten	
	Wet	Dry
	%	%
I. Wheat-couch grass hybrids:		
Hybrid of intermediate type N 43	59.2	20.8
Hybrid of wheat type N 42	52.0	16.0
Hybrid of wheat type N 244b	43.5	15.5
II. Parental forms:		
Wheat lutescens N 062	50.0	17.5
Wheat melanopus N 069	47.8	16.0
Couch grass *Agropyron elongatum*	68.8	25.0
Couch grass *Agropyron intermedium*	52.5	18.0

The occurrence of gluten in the grain of couch grass changes radically the previous conception according to which gluten has been ascribed to wheat only. According to Dr. N. B. Cicine (Izvestia, 4/IV-1936), M. M. Samsonov, the assistant of the West Siberian Grain Institut, has found in the grain of couch grass (*Agropyron elongatum*) 65.1% of wet gluten, which coincides almost absolutely with our results.

Name of species	Gluten	
	Wet	Dry
	%	%
Agropyron caninum	44.5	17.0
Agropyron ugamicum	traces	
Agropyron tenerum	65.6	25.6
Agropyron cristatum	none	
Agropyron desertorum	none	
Secale fragile (Wild rye)	none	
Ægilops squarrosa	84.0	27.0
Ægilops variabilis	90.07	32.0
Elymus sibiricus	36.5	14.5
Elymus virginicus	56.5	18.5
Elymus giganteus	74.0	23.2
Elymus junceus	25.5	10.5
Hordeum secalinum	56.5	20.0

Evidently the number of species capable of gluten formation is much larger. Recently several representatives of different genera have been investigated by us that, according to numerous authors,

are more or less connected phylogenetically with wheat. It was shown that except for the above couch grass species, gluten is present in wild barley (*Hordeum secalinum*), in *Ægilops* and *Elymus* species. No gluten has been recorded in the group of couch grass species such as *Agropyron cristatum* and *desertorum*.

The physical properties of the gluten present in the above species are rather different. Some species are characterised by a very weak gluten which gets broken immediately by stretching out, or their gluten is extremely tough like that of defective wheat.

Gluten of the species—*Hordeum secalinum*, *Agropyron caninum*, and *Elymus sibiricus* shows rather high physical properties. Gluten varies considerably with regard to its colouring as well. Mostly dark shades prevail—ashen gray, dark green, violet, deep yellow, and brown.

It is quite evident that the character of gluten occurrence in grain can be of great value for the stating of philogenetic relationship between the species.

The occurrence of gluten in several couch grass species and their ability to cross with wheat confirms the statement made by S. M. Veroushkine [1] suggesting the close relationship between these couch grass species, wheat and *Ægilops* and a more distant one between couch grass and rye. The above fact confirms another supposition as well, namely, that the genus *Agropyron* is not uniform. *Agropyron cristatum* and *Agropyron desertorum* have no gluten and are more distantly related to wheat than *Agropyron elongatum* and *Agropyron intermedium*. The genus *Hordeum* is also non-uniform. It includes all the cultivated barley species without gluten and wild barley species that have, according to our data, rather high quantities of gluten.

Gluten has been found in the representatives of seven genera of *Gramineæ* families, without counting wheat. The above series does not include all the species distinguished by the occurrence of gluten. The presence of gluten in grain of cereals is not rare, and there are no doubts that further investigations will identify several other species with gluten.

Recently, related wild species are being widely utilized in plant breeding for the improvement of wheat varieties. Therefore, it is most necessary for biochemistry and technology to study in a more detailed way the chemical constitution and baking qualities of the grain of these species.

[1] Veroushkine, S. M., Hybridization of *Triticum* and *Agropyrum*. Monograph published in Caratou, U.S.S.R. (1935); Family connections between *Agropyrum* and *Triticum*. Botan. J. U.S.S.R. (1936).

THE DEVELOPMENT OF THE "STANDARD" A.A.C.C. STANDARD BAKING TEST

QUICK LANDIS and CHARLES N. FREY

The Fleischmann Laboratories, Standard Brands Incorporated,
810 Grand Concourse, New York, New York

(Received for publication February 20, 1937)

Since the collection of baking test formulas by Fitz [1] in 1924, unsuspected difficulties have arisen in the development of a standard test, which have stimulated research activities to a remarkable extent. The proposition to standardize has had unexpected repercussions in the field of cereal chemistry.

While the attempt to standardize has met generally with wholehearted approval in this country, the means to use in accomplishing this objective have been a subject of serious disagreement. On the one hand is that school who would regard flour, for example, as a single ingredient, and feel that a rigid formula and procedure must form the basis of any standard test; on the other those who would break the flour complex into various factors, and then treat with each of these simpler phenomena as a single ingredient, or reagent if you will, of the test. Since this leads to the use of a variable formula it has been conceived to be an unscientific, heretical point of view by the "Fixed Type Procedure" school. The question is discussed at some length in Part II of a paper recently published entitled "The Enzymes of Flour in Relation to Yeast Fermentation" (Cereal Chem. 13: 281 (1936)). While many tend to adhere to the latter viewpoint they have nevertheless gladly collaborated in the development of the test along the lines of the former.

Now, after only 12 years of work, directed primarily from the "Fixed Type Procedure" viewpoint, it is proposed to "standardize" the test by ultimatum. But upon what basis? Even the equipment—pans, proof boxes, punching and molding machines, ovens,—excepting perhaps only mixers, are still not only unavailable as standardized units but are actually yet in the stage of development. The original formulae have been subject to such changes that only in very few cases are they used as such. Finally, the few collaborative studies which have been made with the test have been extremely disillusioning, and no test should

[1] Fitz, L. A. Formulas and method of procedure for experimental baking tests. Cereal Chem., 1: 251–260 (1924).

be adopted as standard until after a considerable period of successful collaborative effort, especially none so complex as the baking test.

But if in spite of these considerations the decision to standardize the test at this time should be reached, and we should specify that "*one* oven, made by *one* manufacturer," or molder, or pans, be used, we fear for the consequences of such a procedure. Which oven, or which pans should be selected? We believe that it will be nearly impossible to get a representative group of cereal chemists to agree upon items of equipment, structure of formula, conditions of procedure, and, finally, interpretation. Even should a compromise be effected, and the resulting standard procedure promulgated without an extensive period of collaborative testing, we feel the chances are too great to risk, that it will be doomed to failure.

It seems to us to be a short-sighted policy to consider only two alternatives. We need not follow the questionable procedure of promulgating an ultimatum covering the procedure of the test. Nor should we discontinue the efforts to reach a standardization of test baking. Let us rather, if you prefer, present to the trade and to the world at large, a progress report covering the first ten years, in which the heretofore unsuspected difficulties inherent in the undertaking and the modifications of the fundamental philosophy of the test required by them may be adequately stated.

The research activities fostered by the Baking Test Committees are too valuable to discard.

BOOK REVIEW

The Biochemistry of the Lipids. By Henry B. Bull. Published by John Wiley and Sons, Inc., New York, N. Y. 169 pages. 1937. Price $2.75.

The mimeographed manual published by Dr. Bull in 1935, and reviewed in this journal (Vol. 12, p. 714), has metamorphosed into the present book. As the author of the book has made clear in the preface, this is not designed to be a technology or dictionary of fats and oils, and the discussion of methods has been confined to an outline of the mere essentials. On the other hand, the chemistry of the fatty acids, soaps, fats and oils, sterols, phospholipids, cerebrosides, alcohols, waxes, and hydrocarbons encountered in natural lipids has been developed in very convenient and useful form. In addition there is a chapter on emulsions. The chapter on fats and oils includes a discussion of the various types of rancidity. This is followed by a discussion of drying oils.

Aside from its generally useful qualities, this book is unique in the generous use of graphs in presenting the relationships between various properties of the materials under discussion. Those of us who are acquainted with Dr. Bull's principal research interests are not surprised to find that these are given a physico-chemical bias whenever that is possible. Accordingly, the book is plainly stamped with the author's personality and moves in an orderly and systematic manner to the elucidation of the primary occasion for lipid properties whenever the available data are adequate to that end.

Physiological aspects are not overlooked, however, as these pertain to plant and animal metabolisms, and the discussions of these phases are interwoven with the treatment of the physico- and organic-chemical treatment of the specific materials involved.

C. H. BAILEY

ANNUAL REPORT OF TREASURER

M. D. Mize

January 1, 1937

Again, it is a pleasure to submit to you an Annual Financial Report showing an increase in the size of all Association activities and still maintaining a substantial surplus in income over expenditures in each account.

It will be noted that the Association experienced the largest increase in membership that has occurred during the past ten years. It is interesting to note that exactly the same number of new members joined the Association this year as was added to the membership in 1923 by the amalgamation with the A.S.M.B.T. The total membership for the first time has crossed the five hundred mark and from the number of prospective new members in sight, this rate of increase will most likely continue.

The sale of "Cereal Laboratory Methods" is continuing at an excellent rate and it appears that the twelve hundred copies printed in 1935 will be sold within the next year. This certainly shows that there was a real demand for this book. Orders have been received from chemists located in practically every country in the world.

The general form of this report has been maintained the same for several years with the hope that every member will thus receive the greatest amount of information from it; especially as it is very easy to compare directly every account with the report of previous years. With this in mind, it seems hardly necessary to take further space to analyze the details of this report.

DETAILED MEMBERSHIP STATEMENT DECEMBER 31, 1936

	Total	Active	Corp.	Hon.
Membership, Dec. 31, 1935	492	445	45	2
New members added during 1936	51	51	—	—
Members reinstated during 1936	17	15	2	—
Members resigned and suspended for non-payment of dues during 1936	*19*	*19*	—	—
Members deceased during 1936	*2*	*2*	—	—
Members in good standing Dec. 31, 1936	539	490	47	2
Net increase in membership during 1936	47	45	2	—

PROFIT AND LOSS STATEMENT

January 1 to December 31, 1936

RECEIPTS 1936			
Cereal Chemistry			
Membership Dues			
Active		$1,722.00	
Corporation		470.00	
Subscriptions, reprints, back issues and advertising	$4,906.38		
1936 Accounts Receivable	1,166.96		
1935 Income received in 1936	*867.92*		
Net 1936		5,205.42	
Interest on Invested Funds		42.62	
Miscellaneous Income		3.50	
Total Net Receipts 1936			$7,443.54

Association			
Membership Dues		1,715.00	
Application Fees		153.00	
Interest on Invested Funds		55.74	
Dallas Convention Registration Fees		124.67	
Miscellaneous Income		3.50	
Total Net Receipts 1936			2,051.91
Cereal Laboratory Methods Sales during 1936			517.59
Decennial Index			
Received from Cereal Chemistry and Association			162.50
TOTAL RECEIPTS OF ALL ACCOUNTS 1936			$10,175.54
DISBURSEMENTS			
Cereal Chemistry			
Cost of printing Journal and Reprints	$5,669.55		
1936 Accounts Payable	1,158.70		
1935 Accounts paid in 1936	*1,534.86*		
Net Cost of Printing		$5,293.39	
Cost of Editing and Miscellaneous Expenses	1,732.03		
1936 Accounts Payable	106.82		
1935 Accounts paid in 1936	*26.83*		
Net Cost of Editing		1,812.02	
1935 Accounts Uncollectable		10.22	
Decennial Index—Cereal Chemistry's 1936 Assessment		81.25	
Net Disbursements 1936			$7,196.88
Surplus 1936			$ 246.66
Association			
Expenses of President's, Vice-President's Office, News Letter		363.42	
Expenses of Secretary's Office		221.33	
Expenses of Treasurer's Office		238.50	
Committee Expenses		55.35	
Dallas Convention Expenses covered by Registration Fees		124.67	
Dallas Convention Report		308.60	
Decennial Index—Association's 1936 Assessment		81.25	
Osborne Medal Award		263.52	
Miscellaneous Expense		14.95	
Net Disbursements 1936			1,671.59
Surplus 1936			380.32
Cereal Laboratory Methods			
Printing, Mailing, Advertising Expenses			214.67
Surplus 1936			302.92
Decennial Index			
Surplus 1936			162.50
TOTAL DISBURSEMENTS OF ALL ACCOUNTS			$10,083.14

DISTRIBUTION OF NET ASSETS

Cereal Chemistry Assets 1935		$4,083.08
Surplus 1936		246.66
Depreciation in Investments [1]		*500.00*

Assets Dec. 31, 1936		$3,829.74
Association Assets 1935	3,276.50	
Surplus 1936	380.32	
Depreciation in Investments [1]	*500.00*	
Assets Dec. 31, 1936		3,156.82
Cereal Laboratory Methods Reserve Fund 1935	474.82	
Surplus 1936	302.92	
Assets Dec. 31, 1936		777.74
Convention Reserve Fund 1935	649.16	
Assets Dec. 31, 1936		649.16
Decennial Index Fund 1935	*325.00*	
Surplus 1936	162.50	
Deficit Dec. 31, 1936		*162.50*
Experimental Laboratory Baking 1935	80.95	
Assets Dec. 31, 1936		80.95
TOTAL ASSETS DEC. 31, 1936		$8,331.91

FINANCIAL STATEMENT DECEMBER 31, 1936

ASSETS

Rutherford National Bank—Checking Account	$1,985.75
Petty Cash Fund—Washington, D. C.	200.00
Emigrant Industrial Savings Bank—New York	816.16
Franklin Savings Bank—New York	500.00
Harris Trust Co.—Chicago	1,928.56
Building & Loan Stock—Kansas City [1]	1,000.00
U. S. Treasury Bonds	2,000.00
1936 Income Receivable	1,166.96
GROSS ASSETS	9,597.43

LIABILITIES

1936 Accounts Payable	*1,265.52*
NET ASSETS	$8,331.91

REPORTS OF THE AUDITING COMMITTEES

We have examined the books and the report of the Treasurer for the year 1936 and to the best of our knowledge and belief these are a true and accurate account of the receipts and expenditures of the American Association of Cereal Chemists.

H. K. PARKER, *Chairman*
CHAS. A. GLABAU
B. R. JACOBS

We have examined the books of the Managing Editor of CEREAL CHEMISTRY for the calendar year 1936 and find the same to be correct to the best of our knowledge.

J. A. LECLERC
L. H. BAILEY

[1] This asset represents $2,000.00 stock in the Benefit Savings and Loan Association, Kansas City, which has been in bankruptcy for several years. Since it is impossible to determine the value of this stock or predict when it will be liquidated, the Executive Committee, at the 1936 Convention, voted to carry this asset in these records at 50% of its face value.

Note: All amounts in italics are negative amounts and are subtracted from the other amounts in the same column.